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NOTES ON THE OCCURRENCE OF OIL AND GAS ACCUMULATIONS IN FORMATIONS HAVING MONOCLINAL DIPS.[1]

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INTRODUCTORY STATEMENT.

The purpose of this paper is to throw some light on the causes which have led to the accumulation of oil and gas in pools where the dip of the containing sand is *monoclinal,* that is, where it is entirely in one general direction, without definite anticlines or synclines. These pools may be included in subclasses I. (*c*) and I. (*d*) of the classification proposed by the writer.[2]

PROPOSED CLASSIFICATION.

This classification is based upon the assumption, which seems to be thoroughly warranted, that all petroleum or natural gas accumulations of sufficient magnitude to be classed as "fields" or "pools" may be separated into classes according to their geological structure. The history of development in any pool or field has shown that the accumulation was due to some definite structure, though often modified by the internal texture of the sands, and by the characteristics of the contiguous overlying and

[1] Paper read before the Geological Society of America, at Pittsburg, Pa., December 29, 1910.

[2] ECONOMIC GEOLOGY, Vol. V., No. 6, 1910, pp. 503–521.

underlying formations. Hence the accumulations are susceptible of being divided into at least seven major classes, and these in turn are divided into subclasses based on minor structural characteristics. In the classification as thus far perfected, only class I. has been subdivided, but if the general scheme meets favor with geologists other details will be worked out from time to time according as fresh data come to hand.

The classification, as proposed to date, is as follows:

CLASSIFICATION OF OIL AND GAS ACCUMULATIONS.

I. Where anticlinal and synclinal structure exists.
   - (*a*) Strong anticlines standing alone.
   - (*b*) Well defined anticlines and synclines alternating.
   - (*c*) Monoclinal dips.
   - (*d*) Terrace structures.
   - (*e*) Broad geanticlinal folds.
   - (*f*) Overturned folds.

II. Domes, or quaquaversal structures.
III. Sealed faults.
IV. Oil and gas sealed in by asphaltic deposits.
V. Contact of sedimentary and crystalline rocks.
VI. Joint cracks.
VII. Surrounding volcanic vents.

Class I., which includes accumulations associated with anticlinal and synclinal structure, consists of six subclasses, according to the form and other characteristics of the anticlines. Where monoclinal dips alone exist, the crest of the anticline and the base of the syncline are so far distant that they may be disregarded in considering the causes of the local accumulation. Terrace structures are merely a variety of monoclinal structures, and were classed by Orton[1] as "arrested anticlines." I wish now to subdivide Class I. (*c*) as follows:

I. (*c*) Monoclinal dips.
   1. Where the accumulations are due to interruption or change in rate of dip.

[1] Edw. Orton, "Geology of Ohio," Vol. 6, p. 94, 1888.

2. Where the accumulations are due to thinning out or change in texture of the sand in some direction.

The best known examples of the distinctions between the different types of structure in Class I. come from Ohio, West Virginia and Pennsylvania, where some of the largest oil and gas fields exist. A generalized cross section of these fields, so far as the monoclinal dip is concerned, is shown in Fig. 1. In this

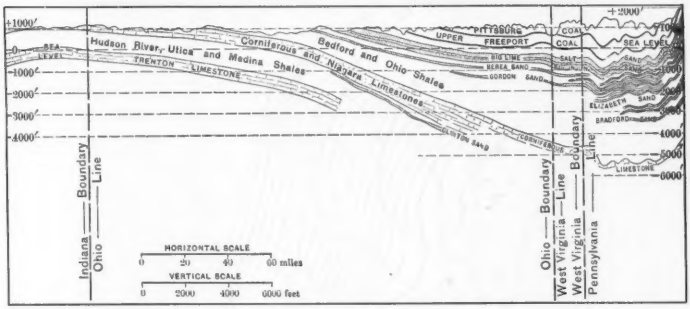

FIG. 1. Generalized cross-section from the Cincinnati anticline to the Allegheny Mountains, to show different types of structure.

section, the pools of subclass I. (*e*) are found on the crest of the Cincinnati geanticline in northwestern Ohio and northeastern Indiana, the oil and gas being contained in the Trenton limestone. The pools of subclasses I. (*c*) and I. (*d*) are on the broad monoclinal dip of over 200 miles extending across central and eastern Ohio; in which fields the oil and gas occur in the Clinton and Berea sands. Somewhat west of the Pennsylvania boundry line the dip becomes stronger and more variable, changing the monoclinal dip laterally into definite anticlines and synclines, and it is in these structures that pools of subclass I. (*b*) are found. Anticlinal and synclinal structures become more and more prominent eastward, until in west-central Pennsylvania and in eastern West Virginia the dips become too sharp to hold any accumulations of oil or gas, these substances, where they once existed,

having presumably escaped to the surface long ago and disappeared.

GENERAL FEATURES OF THE MONOCLINAL STRUCTURE.

As has been explained, Class I. (*d*) is merely a variety of I. (*c*), the two types of monoclinal structure grading into each other insensibly. A monoclinal dip is seldom, if ever, perfectly

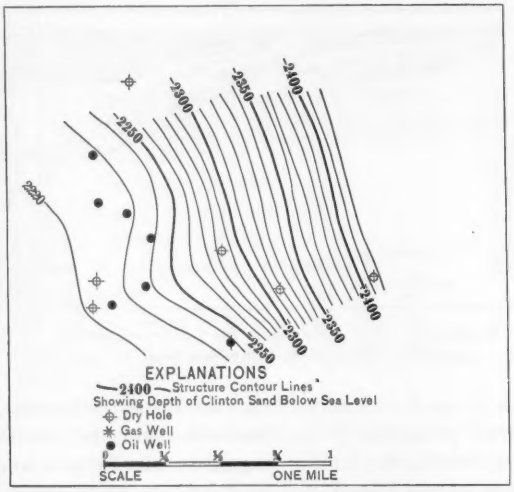

FIG. 2. An example of structural relations of an oil pool situated on a monoclinal dip, in southeastern Ohio [type I. (*c*) 1].

uniform for many miles continuously, and it commonly has many changes of dip in short distances. Figs. 2 and 3 are examples of monoclinal structure in Ohio: the "lay" of the productive sands being represented by structure contour lines. The rate of dip ranges from 20 feet per mile to 200 feet per mile, according to locality. The steeper dips are more often confined within small areas, while the gentler dips are frequently uniformly continuous for many miles. The geological strike of the productive forma-

tions in Ohio is more commonly north and south, or northeast and southwest, with local fluctuations.

The accumulation of oil and gas in most of the eastern Ohio pools are contained in either the Clinton or the Berea sand. These sands vary from a vertical distance of 1,600 feet apart in central Ohio to an unknown distance, estimated as at least 6,000 feet, along the Pan-Handle of West Virginia. The rate of

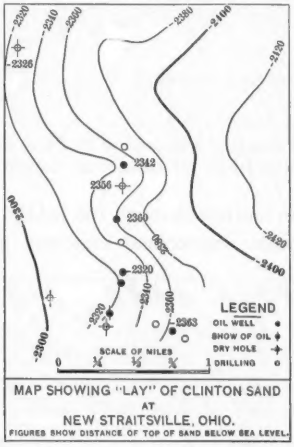

FIG. 3. Structural relations of an oil pool in the Bremen fields of southeastern Ohio, situated on a monoclinal dip [type I. (*c*) 1].

change in interval is fairly uniform, in any particular locality, but varies from 20 to 100 feet per mile in different places, as determined by well records. The change is generally so uniform in any locality that the geological structure of the Clinton sand can be calculated to a close degree of accuracy, when once the structure of the Berea, or of the strata outcropping at the surface, has been determined.

GENERAL STRUCTURAL RELATIONS.

In any stated field, oil and gas exist after certain methods of "habit," which seem to be more or less true throughout that

field. This is because, while these substances adhere to their relations to the principles of the original "anticlinal theory," there are modifying conditions which cause certain structural

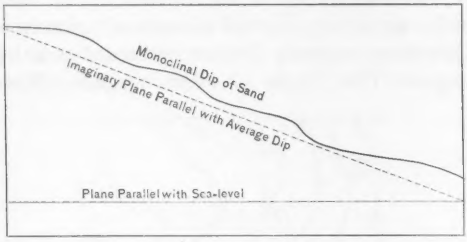

FIG. 4. Diagram showing how a monoclinal fold may be considered a series of anticlines with reference to an inclined plane.

peculiarities to run entirely through the field. For instance, the Ohio fields owe their monoclinal structure to the Cincinnati

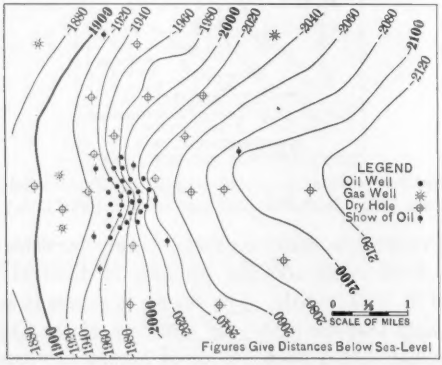

FIG. 5. Example of a structural "ravine" in the Clinton sand in southeastern Ohio [type I. (*c*) 1].

uplift; they are too far from the Allegheny Mountains to be subject to the prominent folds produced in Pennsylvania and West Virginia, but they all show certain *tendencies* toward anti-

clinal structure, as exhibited by terraces, and by changes in rate of dip in short distances.

Again, our common conception of an "anticline" is really not an absolute one; for what is not an anticline with reference to sea-level may become one if considered with reference to an inclined plane with its surface approximately parallel to the average dip

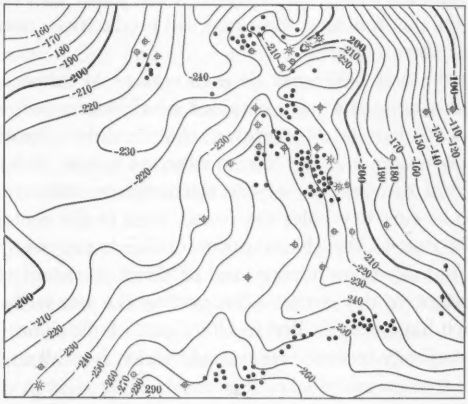

FIG. 6. Example of a structural "ravine" in the Berea sand in southeastern Ohio [type I. (*c*) 1] (after Griswold, Bull. 318, U. S. Geol. Survey, 1907).

(see Fig. 4). Considered in this light, the points of change in rate of dip become anticlines and synclines, forming interruptions in the dip.

Moreover, the formations have evidently been subjected to some slight pressure in a north-south direction, which has produced what might be termed "structural ravines," "notches" or "grooves" in the sand, their axes running in a general east-west direction (see Figs. 5 and 6).

CAUSE OF ACCUMULATION OF SUBCLASS I. (*c*) 1.

In searching for the cause of the accumulation of oil in pools such as the Bremen, Straitville, Junction City, Mingo, Cadiz and

other pools in strata of monoclinal dip in Ohio, the first step was the collection of numerous well records and data from which to determine whether the porous character of the productive sands was limited to the productive areas, whether the sands disappeared on the borders of the pools, whether they thinned out, whether the internal character of the sand changed in any way so as to make it incapable of holding oil, whether it thickened or thinned, or whether on the contrary the areas of productivity were independent of these features.

During the first field work done in regions of monoclinal dip, several years ago, data were obtained which subsequent evidence in many fields has not overthrown; that is, data indicating that the gas, oil, water and dry areas, were, as a rule, independent, in their local distribution, of the character or thickness of the sand. To be sure dry holes are found, even in the center of the best pools, due to the thinning out or hardening of the sand locally. And dry holes having sand of these characteristics exist also in extensive dry areas. But among the hundreds of dry holes which have been drilled in Ohio, east of the main gas belt, the great majority seem to contain sand which is to all appearance as good in texture and thickness as most of the sand in which oil and gas are found. This conclusion was reached in part by personal examination of samples, and in part by talking with the drillers of the wells.

The question then arose whether hydrostatic or hydrologic conditions may not have been responsible for the position of the accumulations. To a certain extent this seemed to be true; since many of the oil pools in the Berea sand particularly are bounded on their down-dip sides by pools of salt water, but following the hypothesis further, it was found that still farther down the dip other oil and gas pools existed, which in turn were usually bounded by salt water pools on their down-dip sides. The best known example of this condition is along the Ohio River in the Pan-Handle of West Virginia and its vicinity, where pool after pool has been discovered by the oil men, the last pools to be discovered being farthest down dip, in the vicinity of Wheeling.

It seems probable that the limit is not yet reached, and similar pools are expected even farther south. It is interesting to note, in this connection, that some of the pools farthest down dip are gas pools, instead of oil pools as might be expected.

A similar condition of affairs was found in the development of the Bremen oil fields in the Clinton sand of Perry and Fairfield Counties, Ohio. The Bremen pool there is down dip east of the central Ohio gas belt, and still farther down dip the Flagdale, Junction City and other pools were found. Between all of these pools barren areas exist for short distances. While it is true that in some of these barren areas the sand was found to be locally hard, thin or close, it is equally true that in the great majority of cases the sand maintains its wonderfully uniform character without regard to whether it holds oil or whether it is dry.

The hydrologic aspect of the situation in the Clinton sand fields is rather difficult to ascertain on account of the great amount of water in the Niagara limestone, which has to be cased off by the drillers, but is frequently only partially eliminated. The Clinton sand, as a rule, is very close, more so than almost any other oil sand in this region, and it apparently holds little water. Whether water be present in the Clinton sand or not, we can safely assert that the entire portion of the sand, down dip from the oil pools, is not saturated with water, as has been assumed by some writers in other fields. The fact that the pools are duplicated in passing down the dip, that between them are frequent local gas-producing areas in the same sand, and that the distribution of the water pools (in the Berea sand at least) partakes in a measure of the distribution of the oil pools, shows that water was not the main factor in the accumulation. The distribution of the water pools should be considered a part of the same problem as the distribution of the oil pools, and what will explain the one may be expected also to explain the other.

One other important factor remains to be considered; that is *structure*. When this is worked out in detail for any particular field the conclusion is reached in nearly every case that the

peculiar structures which are associated with the oil pools are too multifold in their correspondence to be attributed to mere chance agreements. *When considered in a broad light, the common feature of all the oil pools seems to be their occurrence at points of interruption in the general continuity of the dip.*

Types of Interruption.—On a monoclinal dip there seem to be two main types of interruptions: (1) Those due to *longitudinal* warping parallel with the direction of strike of the sand, and (2) those due to *lateral* warping, parallel with the direction of dip of the sand.

The first type produces merely a *change in rate* of dip, illustrated by Fig. 2, where the contours are closer together at the places of steep dip, and farthest apart at places of gentle dip. The exact locality of change in grade seems to be favorable for oil accumulation. The second type of interruption produces a "ravine" or "notch" in the monoclinal slope of the sand, as in Figs. 3, 5 and 6. This is an evidence of pressure from north to south, and such warpings are common in the Ohio fields. This ravine-like structure, being the most marked type of abnormality in monoclinal dips, seems to be very favorable for oil. Actual calculations of the "lay" of the Clinton sand on a wide scale have shown that where type 1 and type 2 intersect, as in several places in the Bremen fields, the largest accumulations of oil are found.

On the basis of hundreds of square miles in which the "lay" of the Clinton sand has been mapped, it has been found that some such structures still exist undeveloped, which will undoubtedly be in time developed and found to be oil pools.

There seems to be no particular reason why these pools should be limited to the belt within twelve miles of the gas field, where they have been mainly developed; but they may be expected to extend down dip to the east for an unlimited distance, as has been found in the more shallow Berea sand pools. The limiting depth of profitable drilling in these pools is now a restraining factor, but with the subsequent discovery of new and more economical methods, which may be expected in time, it is prob-

able that development will continue to the Clinton and possibly to other sands even beneath West Virginia and Pennsylvania.

CAUSE OF ACCUMULATION OF GAS IN CLASS I. (*c*) 2.

While it has been said that texture or dying out of the sand is not responsible as a rule for the exact positions and limits of the oil pools on monoclinal dips, there are exceptions to this statement. In the Louisiana fields some of the oil and gas accumulations are contained in lenticular sands which thin out or grade into shale laterally.[1] In such cases the relations of oil, gas and water in the sands are similar to their general relations in any other monocline, except that the outlines of the pools are bounded by the

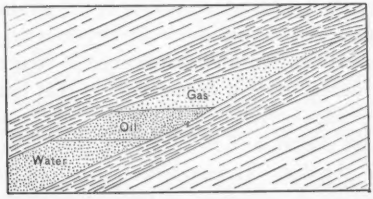

FIG. 7. Pinching out of a monoclinal oil and gas sand, in Louisiana [type I. (*c*) 2]. (After Harris, Bull. 429, U. S. Geol. Survey, 1910.)

extent of the sands (see Fig. 7). Similar lenticular sands are abundant in the California fields, and similar structural relations there are described and illustrated by Arnold.[2]

In the case of the gas belt of central Ohio, the field is bounded a short distance west by the thinning out and entire disappearance of the sand. This is in accordance with the general thinning out of all formations towards the Cincinnati geanticline. Why the gas field does not extend up dip in all localities to the line of entire disappearance of the sand has not been explained, but it may be for the same reason that some of the gas fields on anticlines are situated a few thousand feet distant from the exact geological

[1] G. D. Harris, Bull. 429, U. S. Geol. Survey, 1910, pp. 128–129.
[2] Ralph Arnold, Bulletins 309 and 398, U. S. Geol. Survey, 1907–1910.

crest of the anticline. Some breaks in the continuity of the gas belt seem also to be caused by a thinning or hardening of the sand.

Although some of the California oil accumulations have been caused by pinching out of the sands, certain of them are due to intersecting faults.[1] These latter constitute a special type of monoclinal accumulations and they are therefore included under Class III.

Another special type exists in the Florence field in Colorado,[2] where, although the structure is monoclinal, the oil occurs in fissures in the Pierre shale. This type, however, is placed in Class VI., the accumulations not having been caused primarily by the monoclinal structure. In Class III., at least, the accumulations occur in proximity to the interruptions in the strata, in a similar manner to type I. (*c*) 2, and this coincidence is another point in favor of the universal controlling influence of structure.

Another evidence, derived from Ohio, is that long monoclinal dips for many miles correspond to regions where only showings of oil or gas are found, and in such localities there is very little interruption to the dip. The evidence seems conclusive that the oil has been widely disseminated in the porous strata, and that it has been ultimately accumulated at favorable positions where the regularity of the dip is interrupted locally. The gas, in such cases, has collected on the up-dip side, where the sand is interrupted by pinching (according to type I. (*c*) 2), out or by local flattening (according to type I. (*c*) 1). The oil has collected on the down-dip side, and particularly where the change in rate of dip is most pronounced. In the Bremen fields it has been observed that the most productive oil wells are situated at the points of greatest change in the rate of dip.

[1] Ralph Arnold, Bull. 309, U. S. Geol. Survey, 1907, p. 164.
[2] Chester W. Washburne, Bull. 381–D, U. S. Geol. Survey, 1909, pp. 45–72.

THE HALOGEN SALTS OF SILVER AND ASSOCIATED MINERALS AT TONOPAH, NEVADA.

J. A. Burgess.

OCCURRENCE AND GENESIS OF THE SILVER HALOIDS.

The halogen salts of silver have been found in considerable abundance in the Tonopah ores, and the manner of their occurrence in this place is such as to throw some light on the way in which they were formed. It is characteristic in silver mines located in desert regions, to find metallic chlorides, and to a less extent bromides and iodides, in the oxidized parts of the veins, since the downward percolating waters effecting the alteration of the sulphides are charged with alkaline haloids. Penrose[1] has discussed the formation of haloids in arid regions and cites localities where they have been abundantly formed by the action of surface waters.

Character of the Veins.—The ore at Tonopah occurs almost entirely in quartz veins in the "earlier andesite,"[2] a rock which was so named by Spurr in his professional paper on this region, but which has been more recently determined by him to be trachyte. Much of this rock is covered with a capping of "later andesite" and where so covered the ore consists mostly of primary sulphides, but where the "earlier andesite" outcrops the ore is much oxidized and it is in this oxidized material that the silver haloids are found. The primary ore consists of gold, argentite and the sulphosalt of silver, polybasite, in a gangue of quartz and adularia feldspar. In subsidiary amounts pyrite, chalcopyrite, rhodonite and various carbonates are also present.

[1] R. A. F. Penrose, Jr., "The Formation of Haloid Compounds in Ore Deposits in Arid Regions," *Journ. Geol.*, 1894, Vol. 2, p. 314.

[2] J. E. Spurr, "Geology of the Tonopah Mining District, Nevada," U. S. Geol. Surv. Professional Paper No. 42, 1905. J. A. Burgess, "Geology of the Producing Part of the Tonopah Mining District, 1909," Economic Geology, Vol. IV., pp. 681–712.

The appearance of the characteristic unoxidized ore is that of white quartz blotched and banded with black sulphides of silver, and frequently containing much pink rhodonite. The base metal sulphides are inconspicuous. The oxidized ore is stained brown and black with the oxidized forms of iron and manganese, and contains both the silver haloids and the remnants of unaltered sulphides. It also contains various other decomposition products.

The "earlier andesite" and the veins are broken by many faults and by a multitude of small fissures and seams, and where the vein is not protected by capping these have served as channels for the percolation of the waters that have brought about the alteration of the primary ore.

Occurrence of the Silver Haloids.—The three secondary silver salts formed in the oxidized ore are the chloride, cerargyrite; the chlorobromide, embolite; and the iodide, iodyrite. They are found as deep as the oxidized ore extends, that is to the 700-foot level. Cerargyrite occurs in far greater abundance than embolite or iodyrite. As regards the distribution of the silver in its different forms, it is probable that in a few places the larger part of it is in the form of cerargyrite, but in general the unaltered sulphides hold most of the silver of the deposit. The commonly associated minerals in the oxidized zone are quartz, sericite, kaolin, talc, gypsum, hematite, limonite, and the manganese oxides. The most thoroughly oxidized veins are usually so crushed and porous as to afford an easy path for percolating waters, and open fissures sometimes occur.

The distribution of the haloids with respect to depth has a significant bearing on their origin. In general it may be said that cerargyrite occupies the upper zone, embolite the middle zone and iodyrite the lower zone of the oxidized veins; or more specifically, where the three minerals are found in a given part of the vein, cerargyrite is the highest and grades downward into embolite, while the iodyrite zone is the lowest and is often rather sharply separated from the embolite zone. These zones are not usually distinct and sometimes two of the minerals are found together; instances occur however which justify their separation

into zones. As an example, iodyrite was found in considerable abundance in the Mizpah vein at the 400-foot and 500-foot levels, between the Mizpah fault and the Desert Queen fault. These faults isolated a rich strip of vein about 50 feet in horizontal extent and left it in a crushed condition favorable to the passage of water. On following this ore upward the iodyrite disappeared and thirty feet above the 400-foot level no iodyrite was found, while greenish embolite was present in some abundance. The character of the transition upward from the embolite was not observed in this place on account of the loss of the upper part of the vein by faulting just below the 300-foot level. The embolite zone is never a well-defined one; while in general occupying an intermediate position between the cerargyrite and the iodyrite, it is usually accompanied by cerargyrite and sometimes by iodyrite.

Genesis of the Silver Haloids.—The alteration of the primary minerals was due to the action of descending oxidizing surface water, which contained in solution salts of chlorine, and a lesser quantity of bromine and iodine salts; and it was from the silver sulphate solutions formed by this water that the haloid silver salts were deposited.

The order of crystallization was chloride, bromo-chloride, iodide; which is contrary to what would be expected from their respective solubilities, since iodide is the least soluble and would be expected to precipitate first. The reason for this reversal may be involved in the complicated set of conditions under which the reactions occurred, and the numerous other minerals present. The most obvious explanation seems to be that the chloride was precipitated first because of the great excess of alkaline chlorides in the solution, and that as the chlorine became reduced in quantity it was partly replaced by bromine, and that the iodide was formed only after the concentration of the other halogens was considerably reduced. The presence of manganese dioxide and sulphuric acid with the liberation of free chlorine, may also have influenced the order of reaction; or the fact that the minerals were deposited in the crystalline form and not as amorphous precipitates, may have modified the results.

The explanation will arise that the order of precipitation may not have been reversed but that the haloid-bearing solutions were ascending instead of descending waters. The objection to this is that this form of alteration occurred only in the veins that outcrop at the surface, and to the greatest extent where the downward passage of water is facilitated by the presence of faults or crushed zones. It did not occur where the veins were covered by capping. The chloride is found in greatest quantity in rich ore close to the surface. The fact that this form of alteration has taken place only in the oxidized and outcropping veins, and to the greatest extent at the places where they were most exposed to the action of surface water, seems to be sufficient evidence of the agency of the surface water in its production.

The condition necessary for the formation of the three haloids in the order in which they are found at Tonopah was the percolation of small quantities of solutions through ore in the process of oxidation; the water travelling at a rate sufficiently slow to permit the diminution by precipitation first of the chlorine and next of the bromine, so that finally the iodine could act as a precipitant. It seems that the conditions best adapted to achieve this result would be a seepage rather than a flow of water. The silver was in no case carried far from the original sulphide ore, and the haloid salts were deposited almost immediately after the oxidation of the sulphide. The water during these reactions is best regarded as a solution of the alkaline haloids, to which a small amount of silver sulphate was being continuously added, permitting the selective precipitation of the silver haloids.

The alteration of iodyrite to cerargyrite or embolite would seem to be an improbable one, since it is a change from a more soluble to a less soluble form, but it seems to have occurred in one locality. In a part of the vein heavily charged with manganese dioxide, corroded crystals of iodyrite were found adhering to psilomelane and closely surrounded with embolite or cerargyrite, the secondary minerals not having been precisely determined. Some of the iodyrite remnants are almost entirely encased in the secondary material in such a way as to leave no doubt of

their relative age and origin. It is probable that the presence of chlorine set free by sulphuric acid and manganese dioxide is accountable for this result.

DESCRIPTION OF THE SILVER HALOGENS.

Cerargyrite.—The silver chloride is most abundant in partly decomposed sulphide ore, or in close proximity to it. It occurs as scales, coatings and fissure fillings, and frequently as minute cubic crystals. In the Mizpah vein, fifty feet below the surface, cerargyrite was found in platy masses one-sixteenth to one-eighth of an inch thick, filling fissures in quartz and adhering tightly to both sides of the fissure, but it is more frequent as coatings on one side of a fissure only. Coatings like this have been found almost completely covering surfaces of four or five square inches. Crystals are found most abundantly in finely crushed ore, and where there is a considerable admixture of altered porphyritic rock. Very perfect crystals are scattered through the soft kaolinized rock. They are translucent with a brilliant adamantine to greasy lustre, usually grayish white in color, but frequently with a faint green or olive tinge. Qualitative analyses seldom fail to show traces of bromine and probably there is a gradation to the chlorobromide.

The crystals are invariably a combination of the cube and octahedron, the cube usually predominating. Many of them are characteristically elongated into tetragonal and orthorhombic shapes. The deposition of the mineral from a solution is well shown in some of the cavities where the crystals have long slender twisted and curved shapes.

Embolite.—The chlorobromide is much less abundant than the simple chloride and was formed under conditions similar to the cerargyrite. It occurs as olive-green coatings and groupings of deformed crystals. Small groups of imperfect cubes are found implanted on massive psilomelane or other gangue material, and some of the best of these crystals show a combination of the cube, octohedron and narrow faces of the rhombic dodecahedron. Specimens are occasionally found with groups of these crystals in

parallel orientation so that bright light reflections are obtained from all at the same angle.

Iodyrite.—The iodide is found commonly as brilliant sulphur-yellow crystals lying loose in fissures in the vein. The largest crystals were accompanied by much flaky brown jarosite which formed a soft, loose matrix that did not interfere with the crystal growth. Other good crystals occurred in a soft, kaolinized substance, but the most perfect ones were found attached to quartz in open fissures. Gypsum is a common associate. One of the largest pockets of iodyrite was found in an open fissure, containing much fine-grained nodular manganese dioxide as loose fragments, in the Valley View vein just above the 500-foot level. These crystals occurred loose and were of a deeper yellow color than usual, and with a somewhat different habit from most of those found. The best specimen found was taken from the Mizpah Vein at a depth of 500 feet and consisted of a lump of small adhering crystals. It weighed six ounces and contained no impurities. The iodyrite also occurs as drusy crystalline crusts and as a powder. No analysis has been made of these crusts, so it is not certain that they are identical in composition with the more perfectly formed crystals.

Iodyrite is interesting as being one of the few representatives of the hemimorphic class of hexagonal crystals. The characteristic habit is a unit hexagonal prism terminated on one end by narrow faces of a steep pyramid (2021) and broad base, while the lower end tapers almost or quite to a point by successive alternations of narrow faces of the same steep pyramid and unit prism. This habit is often modified by the relative sizes of the faces, so that short prismatic, long prismatic, tabular to base or prism, and other subordinate types can be differentiated. The crystals are frequently twinned, with (3034) as twinning plane. Measurements have been made of many of the crystals but the oscillations in the growth of the pyramid and prism have produced horizontal furrows and striations and a step-like structure on most of the crystals for their whole length making good readings impossible. Kraus and Cook have recently described

them, giving several drawings to illustrate types and citing several new forms for the crystals.[1]

The crystals are sectile and often slightly bent or curved even to a distortion of the angles so that readings on one side of a crystal may vary from one to two or more degrees from the corresponding readings on the opposite side. The forms on the crystals which appear to be unquestionable are (0001), (1011), (2021), (3031), (4041), (1010), (2021) and (0001).

DESCRIPTION OF THE ASSOCIATED MINERALS.

Mineral Associations.—The ore deposited at Tonopah is of especial mineralogical interest because of the great variety of associated minerals found with the veins and in the oxidized zone. The successive crystallization of the secondary minerals is well shown in many of the specimens collected, and the majority of the minerals are well crystallized and admit of good measurements with the goniometer. Some of the more prominent and unusual species accompanying the deposit will be briefly described in this paper. The prominent secondary silver minerals in addition to the haloids are argentite, polybasite and pyrargyrite, all of which occur as direct alteration products of the primary sulphides. The oxides of manganese and iron are very abundant and some of the best occurrences of crystals are in immediate association with these oxides. Sulphates, carbonates, tungstates, molybdates and phosphates are all represented by species in good crystal aggregates.

Jarosite.—One of the prominent minerals associated with the iodyrite is the hydrous basic sulphate of iron, jarosite. One of its occurrences is in the form of minute dark brown scales, resembling mica scales. This is found loose in broken quartz sometimes with yellow iodyrite. Under the microscope these plates are seen to be brown and golden yellow basal plates of rhombohedrons. The mineral also is found as fine drusy crystallizations lining cavities and seams in ferruginous rock. A later

[1] E. H. Kraus and C. W. Cook, "Iodyrite from Tonopah, Nevada," *Amer. Journ. Science,* 1909, Vol. 27, p. 210.

generation of larger crystals with brilliant vitreous luster occurs implanted on the druses and on thin coatings of wad or manganese dioxide. These larger crystals are a combination of the base and unit rhombohedron in approximately equal development, resembling cubes with tetrahedrons. No analysis has been made to determine whether the crystals are true jarosite or natrojarosite.

Hübnerite and Scheelite.—The two tungstates occur associated with the veins but not in large amounts. Hübnerite is found in the cavities of cellular quartz as platy masses showing a good zone of prismatic faces, vertically striated. Some of the thin crystals have a number of pyramidal terminations, but most of the thin plates have broken ends. Light brown scheelite in small masses occurs in the quartz associated with the hübnerite.

Wulfenite.—The molybdate of lead occurs sparingly in some of the porous quartz masses, associated with iodyrite and gypsum of a later generation. Some of the best and most transparent crystals of the silver iodide have been deposited on the thin plates of the wulfenite. The characteristic yellow and orange-red colors of wulfenite are lacking, the plates being practically colorless or with a slight tinge of yellow. The crystals are very thin basal plates with the diametral pyramids on the edges. Barite is in the gangue which carries the wulfenite.

Phosphates.—In some portions of the deposit the porous quartz masses have all their cavities and seams lined with snow-white crystals of apatite. The crystals are very small and of approximately the same size. They consist of short prisms and bases in about equal development, with occasional line faces of the unit pyramid. Bronze-yellow isolated crystals of iodyrite occur implanted on the apatite. The apatite has been covered in places by a flow of pure colorless colloidal silica, forming botryoidal surfaces of glassy hyalite, which is spotted here and there with included yellow iodyrite. Turquoise, the hydrous phosphate of alumina colored with copper, occurs in the form of concretions; and wavellite, another form of the phosphate of alumina is found as little white spherules. These phosphates are all of later age than the body of the ore.

Cinnabar.—This mineral is of a very rare occurrence and is found only in the West End mine, where fissures in the vein are coated successively with botryoidal pyrite or marcasite, and afterwards with botryoidal cinnabar. The cinnabor is of comparatively recent deposition, probably as the result of solfataric action.

The writer is indebted to Professor A. S. Eakle, of the University of California, for the crystallographic portion of this paper.

NOTES ON TELLURIUM-BEARING GOLD ORES.

W. J. Sharwood.

GENERAL.

These notes, commenced in 1909, were at first intended as a discussion of the paper of Lenher[1] in which was summarized much of the valuable work published by himself and assistants during the past twelve years. As unavoidable delay occurred in the preparation, and as they have grown beyond the original subject matter, it seems best to publish them as a distinct paper. A serious handicap in writing has been the inaccessibility of much of the important literature on the subject, but such references as are given have been verified.

One of the points emphasized by Lenher is the frequency of the association of gold and tellurium, but he says further: "It is not at all necessary that gold deposits should contain tellurium; in fact this association may be considered exceptional." On the other hand, my own experience in the examination of a considerable number of gold ores has confirmed the opinion, which has been expressed by Kemp in the résumé concluding his excellent bibliography and list of localities of telluride gold ores,[2] that "tellurium is a more widely distributed and more common associate of gold than has been generally appreciated." By grinding successive faces on a specimen of ore, examining them with a lens, and picking out minute particles of individual minerals for direct qualitative tests, or by selecting single grains from concentrated material, I have detected tellurium in a majority of such ores examined as have contained visible free gold.[3]

[1] "Some Observations on the Tellurides," Economic Geology, IV., 544.

[2] *Mineral Industry*, VI., 295–320, 1897.

[3] Some of these occurrences have been briefly described and illustrated in *Mining and Scientific Press*, January 26 and June 8, 1907, CXIV., 117 and 731. It is perhaps only fair to add that most of the ore samples thus examined were from various points in the western United States. Out of eight samples

This system of testing segregated granules is generally preferable to that of dissolving and attempting to precipitate quantities of tellurium expressible in thousandths of a per cent., as it is possible in this way to detect it by the sulphuric acid test in particles of calaverite or tetradymite weighing less than 0.005 milligram; in fact the limit is practically the visibility of the particle. In many cases it has been impossible to determine the nature of the tellurium compound, but in several instances bismuth was also found. The frequency of this association has already been pointed out by Pearce and by Kemp, and it seems too general to be fortuitous. That this is the case is indicated by the following list of occurrences in which gold and tellurium have been recognized as associated with bismuth.

OCCURRENCES OF BISMUTH AND TELLURIUM WITH GOLD.[1]

Highland, Montana, in lode with dolomite, and also in placer (Kemp).
Cable Mine, Montana (calcite, S.); near Quigley, Montana (quartz, S.).
Clear Creek, San Juan, Ouray, and Summit Counties, Colorado (in most cases with fluorite; Pearce and Kemp).
Yavapai County, Arizona (Kemp).
Goldfield, Nevada (with alunite and quartz; Ransome, S.).
California; several instances in quartz fissure veins and "pocket seams" (quartz, or quartz with calcite; in one case quartz and fluorite; S.).
Spurs of Mother Lode system, California (calcite, S.).
Shasta County, California (Kemp).
One occurrence in Black Hills, S. Dakota (calcite, quartz, and fluorite, S.).
Southern Appalachian Belt, numerous instances in Maryland, Virginia, North Carolina and Georgia (see Kemp, and Dana's "System of Mineralogy").
Seward's Island, Hancock County, Maine (calcite and quartz, Kemp).
Yale District, British Columbia (Kemp).
Jalisco, Mexico (Kemp).

tested from Japan and Korea not one showed any indication of tellurium, though several bore a remarkably close resemblance to typical Californian quartzose ores.

[1] Most of the references to Kemp (*loc. cit.*) indicate localities quoted by him from a paper by R. A. Pearce, *Trans. Am. Inst. M. E.*, XVIII., 447; those marked "S." are occurrences which have been personally examined by the writer.

Minas Geraes district, Brazil (Henwood).
Clogau and St. David's gold mines, North Wales (Forbes, *Phil. Mag.* (4), XXIV., 339; Huddart, *Trans. Inst. Min. & Met.*, XIV., 204).
Southern Norway.
Urals, several localities.
Siebenbürge of Transylvania, several localities.
New South Wales, several localities (Mingaye).
Copper ores of Arizona, Montana, and Australia.

CLASSIFICATION OF TELLURIUM-GOLD OCCURRENCES.

The conditions under which these elements occur together admit of a division into several well-marked groups.

1. Gold tellurides proper (which may also contain silver and sometimes other elements).

1*a*. Products of partial alteration of these gold tellurides, yielding free gold on the surfaces or in cracks.

Both of these modes of occurrence are well illustrated in specimens from Kalgoorlie and Cripple Creek (see Rickard, *Trans. A. I. M. E.*, XXX., 708, and XXXIII., 567), and in some from California.

2. Tellurium minerals having free gold deposited on their surfaces, presumably precipitated by reaction with gold solutions. The surface of the original mineral may or may not show signs of oxidation.

This condition is observable in specimens of tellurides containing lead or bismuth (usually somewhat altered) from certain veins or spurs of the Mother Lode of California, and in scattered instances in Montana.

3. Free gold associated with tellurium minerals, apparently deposited either contemporaneously or alternately.

This condition has been noted in some specimens of crystallized gold intergrown with altaite from the "pocket belt" of Sonora (Tuolumne County, California), and in the coarse free gold with bismuth sulpho-telluride of the Cable Mine, Montana. To this class may also belong the deposits of Goldfield, Nevada, where free gold (some of it almost absolutely pure) is associated with a complex antimonial sulpho-salt of copper containing bismuth and tellurium, named goldfieldite by Ransome. An occurrence of wire gold at Carson Hill (Calaveras County, California), mentioned by Ransome in an earlier publication, and an instance from Western Australia (Kemp, *loc. cit.*, p. 319) afford other examples.

4. Free gold associated with tellurium minerals, generally not in contact, and bearing no evidence of either having influenced the deposition of the other.

   As instances of this class may be cited several ore samples obtained from "true fissure" quartz-veins of California, ranging from Siskiyou southward to Tuolumne County; some specimens from Mother Lode mines may also be referred to it. In most cases a lens or microscope is necessary to recognize the scattered grains or scales of the tellurium minerals.

5. Ores containing small amounts (rarely exceeding two or three hundredths of a per cent.) of gold and tellurium associated with sulphides (especially of iron and copper), and which can only be recognized after concentration by analytical or metallurgical processes.

   The copper ores of Australia, Arizona, and Montana represent this type, and some of the "Potsdam" ores of the Black Hills.

6. Free gold associated with tellurium oxide, tellurites or tellurates.

   These may result from oxidation of tellurides in either of the other classes. The gold may be non-amalgamable and sometimes is finely divided; the surface is sometimes distinctly "rusty" or may be coated with an almost imperceptible film of foreign matter.

7. Occurrences of tellurium in detrital deposits with gold.

   These are, as mentioned by Lenher, so rare as scarcely to deserve recognition in a scheme of classification; they are however not entirely unknown. One of the earliest recorded finds of tellurium in Montana is quoted by Kemp as having consisted of scales occurring in a placer. I once found a particle of a gray crystallized tellurium mineral in a small open cavity in a grain of placer gold from Butte Creek, Butte County, California, where it had been protected from wear by the gold.

Ores belonging to the third of the above classes are of particular interest and deserve investigation, as they may give a clue to the nature of the solutions whence they were derived, or to some of the conditions of precipitation of at least these particular ores. This might take place by the simultaneous precipitation or crystallization of free gold and a telluride from a single solution under some change of conditions, as by cooling, or by partial oxidation, or possibly by a complex precipitation in stages as suggested by some of Lenher's results. In the case of the Goldfield occurrences, including those of nearly pure gold with the sulpho-telluride "goldfieldite," Ransome has demon-

strated the probability of the simultaneous deposition of these two minerals being due to rising solutions of sulphides becoming oxidized when approaching the surface, as evidenced by the development of sulphates in the adjacent country rock.

In the case of the clusters of gold-altaite crystals, the two individual crystallized minerals are not only so placed as to make it certain that deposition took place either at the same time or alternately, but the crystals show in some cases well-marked parallel grouping. Both belong to the cubic system and pseudomorphism might be suggested, but they differ in habit, the altaite being mainly in symmetrically developed combinations of cube and octahedron, while the gold inclines to skeleton forms with bold octahedral outlines and unusually brilliant faces, quite unlike those shown by gold pseudomorphs. While some faces of the altaite are pitted, this does not appear to be due to its having been attacked by solutions while acting as a precipitant for the gold, as other subsidiary faces are brilliant, and some of the larger pits are distinct depressed octahedral faces.

The Tuolumne-Calaveras "pocket-belt" from which these crystals were obtained, has yielded many noteworthy masses of free gold, some of great weight and others unusually well crystallized; in many instances these were associated with tellurides, but the conditions of occurrence have varied greatly. The largest masses found in places have come from the Bonanza and O'Hara mines, near the town of Sonora. It is regrettable that no adequate study has been made of these remarkable deposits, which merit investigation, and that only a few brief descriptions have been published.[1] This is due in part to the natural reluctance of owners and lessees to admit visitors at times when rich pockets are in process of extraction.

While the presence of tellurium in veins has in some districts been adduced without reason to indicate their persistence in depth, its association in others with deposits of a pockety or irreg-

[1] California State Mining Bureau Reports, VIII., 652, X., 736, XII., 299; *Mining and Scientific Press*, June 6, 1908, XCVI., 782; U. S. G. S. Geologic Folio, XLI., 7 (Sonora Sheet).

ular character has led to the opposite view. That it is not incompatible with persistence in depth is evident from a consideration of its occurrence in the ores of the California Mother Lode, and of the great depth attained by some mines on that lode. One of the oldest and deepest mines on the American continent is the Morro Velho of Minas Geraes, Brazil, the existence of tellurium in which was mentioned by Henwood,[1] and which, though supposed to be exhausted at the beginning of the nineteenth century, has since been almost continuously worked by the St. John del Rey Co. for eighty years, yielding ore of a remarkably uniform gold content, averaging about half an ounce per ton. This shoot has been followed to a depth of over a mile, as measured on the dip. The famous Idaho-Eureka-Maryland ore-shoot of Grass Valley, California, extends over 5,000 feet in length, and contains tellurium in notable quantities.

While tellurium is present only in minute proportions in the copper ores of Montana, Arizona and Australia, it often far exceeds the gold in amount, as is evident from analysis of metallurgical products, especially of the slime or "anode mud" obtained in the electrolytic refining of the copper, from which part of the tellurium has been removed during the converting or blowing of the matte. Some of the tellurium may however have been originally combined with silver, which always occurs in these ores in much larger proportions than gold. In each of these districts bismuth also occurs in quantities comparable with those of the tellurium. This is shown in the following table:

COPPER AND GOLD ORES AND PRODUCTS CONTAINING TELLURIUM.

The following are items taken from analyses, mostly of large lots of material, and represent percentages of the constituents selected.

1. Average copper ore from Wallaroo Mine, South Australia. T. C. Cloud, *Trans. Inst. Min. & Met.*, XVI., 57.

2. Average of six "high-grade" ores containing free gold, Goldfield, Nevada. F. L. Ransome, U. S. G. S. Prof. Paper, No. 66, p. 169, analyses by Von Schulz and Low, Denver.

3. Matte from ore of Copper Queen Mine, Arizona. E. Keller, *Trans. A. I. M. E.*, 1899.

[1] *Trans. Geol. Soc. of Cornwall*, VI., 295.

4. Matte from ore of Butte, Montana. Private communication; see also Keller, *Trans. A. I. M. E.*, 1898.

5. Raw "anode mud" from electrolytic copper refinery of Great Cobar Syndicate at Lithgow, New South Wales. G. H. Blakemore, *Proc. Australasian Inst. M. E.*, 1910; abstract in *Mines and Minerals*, June, 1910, XXX., 651.

6. Raw "anode mud" from refining copper from ores of Butte, Montana. Private communication.

7. Typical "anode mud." L. Addicks, *Jour. Franklin Inst.*, 1905.

	Ag Per Cent.	Au Per Cent.	Te Per Cent.	Se Per Cent.	Bi Per Cent.
1. Ore, South Australia.....	0.0023	0.0002	0.001	———	0.0012
2. Ores with free gold, Goldfield, Nevada	0.26	1.34	2.13	?	1.12
3. Matte, Arizona	0.020	0.0035	0.0088	0.0113	0.0044
4. Matte, Montana	0.05	0.0003	0.001 to 0.01	0.001 to 0.01	0.03 to 0.05
5. Anode mud, New South Wales	15.725	1.450	0.654		0.707
6. Anode mud, Montana	25.	.05 to 1	2 to 3		2 to 3
7. Anode mud.....	40.	2.	5.		———

TENDENCY OF TELLURIUM TO SECONDARY CONCENTRATION WITH GOLD.

When a secondary concentration of gold is apparent, resulting in the deposition of masses or flakes of relatively coarse free gold in stringers or incrustations of either quartz, fluorite or carbonates, it is in my experience not unusual to find some tellurium mineral also present (not necessarily itself containing gold) even if tellurium is not recognizable in other parts of the deposit. Tetradymite (or some similar bismuth mineral) and altaite have been found several times in such situations.

Thus the Cable Mine of Montana, the Jumper (which includes the Golden Rule from which some of Genth's type material was obtained) and other mines on the Mother Lode of California, and numerous small pocket mines in Tuolumne and Calaveras counties, California, contain coarse free gold in stringers of calcite or dolomite with bismuth telluride. At the Homestake Mine, South Dakota, a single occurrence has been noted of large flakes of gold with calcite and a bismuth-tellurium mineral in the lining of a vugg, while I believe tellurium has never been found in any other part of the deposit.

In a series of samples from the Cable Mine, the low-grade gold ore was found to contain pyrite and pyrrhotite without visible gold or telluride, associated with dolomite containing a little iron. Richer specimens contained coarse free gold in calcite with small grains and crystals of bismuth sulpho-telluride, some enclosed in the gold and others attached to its surface, the calcite containing very little magnesia and including some quartz. This occurrence of tellurium is not mentioned in the list of minerals from this locality in W. Emmons' report on the district,[1] but had been previously noted by Bohn,[2] and by Pierce.[3]

ASSOCIATION OF EXCEPTIONALLY PURE NATIVE GOLD WITH TELLURIDES.

In many instances where native gold has been found of exceptional purity, it has been associated with tellurides. This is the case at Goldfield, Nev., where some of the original free gold, found in the complex mineral goldfieldite, is over 996 fine, though a larger proportion of silver is met in other parts of the deposits. Only a portion of this gold is amalgamable, a considerable part, although evidently in the metallic state, being apparently coated in such a way as to resist the action of mercury and also of cyanide solutions. No definite film of foreign material can, however, be detected with the microscope, and the surface of some of the irregular gold particles is as brilliant as that of Californian or Australian "free-milling" gold. On the other hand, some of it has a distinctly dull, sometimes brownish, surface.[4] At Cripple Creek almost absolutely pure gold was found, and in some specimens of Colorado calaverite the silver is present only in minute proportions. At some of the West Australian mines gold of like purity occurred, bullion from the Great Boulder hav-

[1] U. S. G. S. Bulletin 315.

[2] *Mining Mag.* (N. Y.), 1906, XIII., 373.

[3] *Proc. Colo. Sci. Soc.*, III.

[4] Attempts to determine the nature of this coating have not met with success. After treatment of concentrated gold particles with hydrochloric acid, I have detected iron, tellurium, bismuth, antimony and sulphur in the solution, but in minute amounts which may have been obtained from particles of other minerals adhering to the gold grains.

ing been reported as 999 fine. Much of the gold from these two districts was however of a more or less spongy character, and dull or earthy in appearance. The gold of Mt. Morgan, South Australia, was about 997 fine and non-amalgamable, being also derived from the oxidation of tellurides in ore of the same character as the underlying cupriferous sulphides now being mined there. It has been suggested that the fine, non-amalgamable, gold of Mercur, Utah, associated with realgar and cinnabar, is also derived from an original telluride. At the Passagem mine (Ouro Preto), Minas Geraes, Brazil, gold is obtained 940 to 960 fine by simple concentration, or by cyaniding, from an ore containing bismuth and tellurium.[1] The purest Californian *vein* gold recorded is that of the San Giuseppe mine, near Sonora, one shipment of which to the San Francisco Mint was 998 fine, and several over 990.[2] I am informed that some of this bullion was decidedly brittle, and it is said to have contained bismuth and tellurium. At the Golden Gate mine, in the immediate vicinity of the San Giuseppe and probably genetically connected with it, the gold occurring in a pyritic quartz vein was almost free from silver and for the most part was non-amalgamable, while tellurium could occasionally be detected. In assaying this ore and concentrates from it I have frequently obtained gold buttons over 990 fine.[3] The purest *placer* gold on record, such as that from Ekaterinenburg in the Urals, the Fine Gold hydraulic mine of Vallecito, Calaveras County, and a few other localities in California and Oregon, has not, I believe, exceeded

[1] Bensusan and Kendall, Bull. 73, Inst. Min. & Met., Oct., 1910.

[2] F. A. Leach, "California Mines and Minerals," p. 170.

[3] In comparing reports of the fineness of gold bullion shipments it must be remembered that bars resulting from the chlorination process are practically free from silver, no matter what the proportion in the original ore. On the other hand, in bars obtained by the cyanide process there is a larger proportion of silver to gold than in the *free* gold of the ore; in bars resulting from amalgamation the proportion of silver is also higher, and that of gold lower, than in the *free* gold of the ore; both cyanide and amalgamation bars however contain less silver in proportion to the gold than an assay of the average ore would indicate—some silver being usually present in the ore in combination with sulphur, etc., and only partially extractable by these processes, while the silver alloyed in the native gold may be wholly recovered.

990 fine. That of Vallecito is certainly in part derived from tellurium-bearing lodes.

NOTES ON ANALYSES OF SOME TELLURIUM MINERALS.

The actual composition of the complex mineral goldfieldite, to which the formula $5Cu''S.R_2S_3$ was tentatively assigned by Palmer[1] is somewhat uncertain. In view of its close association

GOLDFIELDITE.

	Found Per Cent.	Atoms.		Atomic Ratio Found.		Atomic Ratios Calculated from Formulas.		
				Unmodified Analysis.	Corrected Analysis.[2]	Enargite type, $3Cu_2S.R_2S_5$	Palmer's formula, $5CuS.R_2S_3$.	Alternate formula, $5Cu_2S.2R_2S_5$.
Copper	33.49	527.	527	30	30	30	30	30
Silver	0.18	1.6						
Sulphur	21.54	671.	804	45.7	43.5	40	48	45
Tellurium	17.	133.						
Antimony	19.26	160.	202	11.5	10	10	12	12
Arsenic	0.68	9.						
Bismuth	6.91	33.						
Gold (free?)	0.51							
Gangue	2.0							
Total	101.57							

FAMATINITE OR ENARGITE OF GOLDFIELD.

	Found Per Cent.	Atoms.		Atomic Ratio Found.	Atomic Ratio Calculated for Enargite Formula, $3Cu_2S.R_2S_5$.
Copper	48.0	754	754	30	30
Arsenic	11.0	146.5	248	9.9	10
Antimony	12.2	101.5			
Sulphur	28.8	900	900	35.8[3]	40

[1] U. S. G. S., Prof. Paper No. 66, p. 116.

[2] Corrected as suggested by Ransome by subtracting the constituents of Bi_2S_3, but in this case subtracting only sufficient to bring the residual As + Sb + Bi to the proportion required for the enargite formula. This leaves an *excess* of S over the requirements of the enargite formula, corresponding to nearly 2 per cent. S in the original analysis.

[3] The *deficiency* in sulphur here indicated corresponds to about 3.3 per cent. in the composition of the mineral proper as tabulated, but to only 1.5 per cent. in the material analyzed, which included much gangue.

with a mineral undoubtedly belonging to the enargite-famatinite type it seems highly probable that goldfieldite itself may be a telluriferous variety or species of similar structure, since a careful examination of the published data shows that the analysis of goldfieldite agrees quite as well with the enargite type formula as does that of the Nevada famatinite analyzed by Schaller and quoted by Ransome, as is seen from the figures tabulated below. The excess or deficiency of certain constituents is not surprising in view of the small amounts of materials available for analysis and of the complications introduced by the presence of certain constituents in the determination of others. The formula sug-

AVERAGE OF SIX ANALYSES OF ORE FROM THE 220-FOOT LEVEL OF THE HAYES-MONNETTE WORKINGS, MOHAWK CLAIM OF GOLDFIELD CONSOLIDATED CO., BY VON SCHULZ AND LOW, DENVER.[1]

	Per Cent.	Atomic Ratio.		Approximate Atomic Ratio.
Tellurium	2.13	16.7	184.4	19
Sulphur	5.38	167.7		
Gold (free ?)	1.34	6.8		
Arsenic	0.14	1.86	9.74	1
Antimony	0.30	2.5		
Bismuth	1.12	5.38		
Copper	2.38	37.4	39.8	4
Silver	0.26	2.4		
Iron	5.72	102.	102.	11
Manganese	0.13	2.3	5.9	
Nickel-Cobalt	0.065	1.1		
Zinc	0.16	2.5		
Alumina	5.665 =	Al 111.		11+
Soda	0.13 =	Na 4.2	9.7	1
Potash	0.26 =	K 5.5		

Some of the sulphur is combined with part of the alkalis and a proportional amount of the alumina, as alunite; a large part of the iron is in the form of pyrite, and much of the bismuth as bismuthinite. The other elements are probably combined as complex sulpho-salts, goldfieldite, famatinite or enargite. The copper is, however, distinctly in excess of the ratio demanded by compounds of this class. Silica and some other constituents are omitted as non-essential to the present purpose.

[1] Ransome, *loc. cit.*, p. 169.

gested by Palmer—indicating a *cupric* thio-antimonite—seems improbable, considering the number of known natural sulpho-salts, in all of which cuprous copper alone has hitherto been recognized. It is remarkable that much of the richer ore of Goldfield shows a still higher proportion of copper to antimony, etc., if the analyses quoted by Ransome are typical. Taking the mean of six analyses which agree pretty closely, it may be seen that the ratio Cu : (As + Sb + Bi) is about 4 : 1 instead of about 3 : 1 as found by analysis in the minerals and as indicated by the enargite formula. This suggests the presence of some other copper mineral, such as chalcocite or bornite. Recent reports indicate that copper minerals are more prevalent at deeper levels.

While the Nevada mineral classed as famatinite by Ransome differs materially from ordinary enargite, and contains more antimony than arsenic by *weight,* attention is called to the fact that the *atomic* percentage of arsenic is considerably greater than that of antimony (As : Sb = 1.45 : 1).

Selenium occurs in appreciable quantities with tellurium in the Goldfield ores, its presence being evident from the deposition of the element from sulphuric acid that has been used in parting, on the large scale, the bullion obtained from southern Nevada mines. It is also present in traces in West Australia gold ores, as well as in the copper ores previously discussed, and (also with tellurium) at the Waihi gold mine in New Zealand. It has also been found in the Republic district of Washington, where the gold is extremely finely divided and not susceptible to amalgamation or direct cyaniding.[1] Selenium also exists in considerable quantities in certain silver-gold mines of Sumatra, but I believe that tellurium has not been reported from these deposits. In all these cases it seems probable that the selenium may be associated with silver. I have also detected selenium in pyritic concentrates from the Rawhide Mine, on the California Mother Lode, together with tellurium and nickel—the concentrates carrying fully 2 per cent. of the last named metal, which suggests the presence of melonite though this could not be isolated.

[1] Chatard and Whitehead, *Trans. A. I. M. E.,* XXX., 419.

It may be recalled here that a later analysis by Hillebrand[1] of melonite, from the same deposit as Genth's type material, shows a close agreement with the formula $NiTe_2$; while Genth's original analysis indicated the composition Ni_2Te_3. Tibbals[2] finds that the precipitate formed in solutions of nickel acetate is hydrated Ni_2Te_3. The anhydrous compound formed at high temperatures is NiTe.

In examining some samples of ore from one of the mines of the Melones group, I obtained about 50 milligrams of apparently homogeneous particles of a lead-gray mineral. Analysis showed that its composition approximated closely to the improbable formula $PbAgTe_4$,[3] though the amount available was of course too small for exact determination.

[1] U. S. G. S. Bull. 167, p. 61.

[2] "A Study in Tellurides," *Jour. Am. Ch. Soc.*, 1909, XXXI., 909.

[3] A consideration of this and a number of analyses yielding tellurium in excess of the proportions demanded by what are usually considered rational formulas, seems to bear out the suggestion made by Lenher that some of the natural tellurides differ from ordinary chemical compounds, and may partake more of the nature of alloys. One argument used by him to support this view appears, however, to be fallacious. It is intimated that natural gold tellurides, in their action toward gold solutions, are "unlike true chemical compounds of gold and tellurium, since we know of no true chemical compound that can precipitate one of its constituents in such a manner as takes place between the natural tellurides and gold solutions." Admitting that these tellurides may be abnormal in some respects, and that similar cases of precipitation, which may be illustrated by the equation

$$AB + AC = 2A + BC,$$

are exceptional or infrequent, is there any logical reason why true chemical compounds should not react thus? Is not the condition requisite for a reaction of this type merely the existence of two compounds of one element with two radicals which can themselves combine directly to yield a stable product? —a condition which is by no means common.

The artificial tellurides, for instance Au_2Te, made by heating the two elements in suitable proportions, react with gold salts like the natural minerals mentioned by Lenher, presumably following the equation:—

$$3Au_2Te + 4AuCl_3 = 10Au + 3TeCl_4.$$

Is there any essential difference between such a reaction and that between the two compounds of sulphur with oxygen and with hydrogen, which takes place on mixing the moist gases:

$$2H_2S + SO_2 = 3S + 2H_2O?$$

In testing for tellurium in minerals by the familiar sulphuric acid method there is a possible source of error, which I believe is not mentioned in the literature on the subject. Some time ago a sample presented for examination was passed on to an assistant who soon reported that it gave a strong reaction for tellurium, which seemed improbable from its general appearance. Further tests proved it to consist largely of manganese peroxide, although a fine purple color developed when it was heated with strong sulphuric acid and then allowed to stand a few minutes. The tellurium test requires that the particles be moistened with the strongest sulphuric acid and cautiously heated nearly to the point at which white fumes rise, the colored compound forming only between rather narrow limits of temperature. Several other specimens containing manganese peroxide were found to yield a similar color when similarly treated and then cooled and exposed a short time to a moist atmosphere; the color could generally be brought out by breathing on the sample while cooling. It is probably due to the formation of permanganic acid.

While this test is an excellent one for clean particles of unoxidized tellurium minerals, it often fails in the presence of large amounts of sulphides such as pyrite, and is useless in the case of oxidized compounds unless previously reduced. G. T. Holloway[1] has described a method of isolating tellurium from ores for testing purposes, by concentrating it with the gold and silver in a lead button obtained by the ordinary fire assay, it being pos-

In metallurgy we have several instances of the practically complete reduction of a metal by the mutual decomposition of two of its compounds—for instance when either of the sulphides of copper is heated with either of its oxides in suitable proportions, the metal is separated. Similarly galena, added to a fused silicate of lead or to molten litharge, reduces the metal, in the latter case quantitatively, though each of the compounds reacting is itself quite stable at the temperature of this reaction.

$$PbS + 2PbO = 3Pb + SO_2.$$

As a somewhat analogous instance may be mentioned the simultaneous separation of oxygen from two of its componds, when a peroxide reacts with silver oxide, or permanganates on peroxides or other oxidizing agents, such as the tellurate mentioned by Lenher.

[1] *Trans. Inst. Min. & Met.*, XVII., 175.

sible to treat as much as 50 or 60 grams of ore in this way. The lead button is then dissolved in nitric acid, diluted, and the tellurium precipitated by means of lead foil, the deposit thus obtained being then dried and tested by concentrated sulphuric acid.

SUMMARY.

The points to which special attention is called are:

1. The frequency of the occurrence of tellurium in gold ores generally.

2. The frequency of the triple association of bismuth with tellurium and gold.

3. The fact that tellurium cannot be taken generally as an indication either of irregularity or of persistence in depth of gold deposits, as it occurs both in the extremely irregular deposits found in pocket seams, and in some of the deepest and most continuous shoots which have been worked for gold.

4. The tendency of tellurium to segregation together with gold in veins where a secondary enrichment has taken place.

5. The fact that exceptionally pure native gold, in almost every recorded instance of its occurrence, has been associated with some tellurium mineral, or derived from a telluride.

THE CLINTON SAND AS A SOURCE OF OIL IN OHIO.[1]

J. A. Bownocker.

INTRODUCTION.

The petroleum industry in Ohio began in 1860 when a well about sixty feet in depth was drilled on the bank of Duck Creek in northern Washington County in the southeastern part of the state. The production was small but it established the presence of the coveted fuel and made further exploration certain. Well after well was sunk and soon Macksburg was known as the most important oil center outside of Pennsylvania. Drilling extended into adjacent counties, until tests were numbered by thousands. Many fine pools of oil rewarded the prospector and he is still searching. However the multitude of tests make future prospects anything but flattering, and it seems safe to state that the petroleum industry in southeastern Ohio is past its zenith and that future reports on it will be those of a declining industry.

In 1884 a well was drilled at Findlay in northwestern Ohio, the result being a strong flow of gas. Other wells were drilled as fast as the tools could be forced to the Trenton limestone and in 1885 oil was found. The latter was dark and heavy and had a pungent odor due to certain sulphur compounds. These facts with its occurrence in limestone prejudiced the oil with the refiners and producers alike. However, the drill was kept going day and night and the production of oil increased rapidly. The price was cut time and again with the hope of stopping the production, until in 1887 the quotation was fifteen cents a barrel. Later, with improved methods of refining, the market improved and with it the price. For several years Ohio ranked first among the states in the yield of oil, but with the establishment of the limits of the field more than ten years ago the production began

[1] Read December 29, 1910, at the Pittsburg meeting of the Geological Society of America.

to fall off and the state lost her position. Drilling is still in progress within the producing borders and outside of them, but probably a half dozen old wells are abandoned to where a successful one is secured. This field has had its day and the yield will be smaller and smaller each year, though it will doubtless be a commercial source of oil for many years to come.

With the conditions just stated in the two great oil sections of Ohio, the prospector began looking for new oil-bearing strata. First he tried to find in the extreme eastern part of the state the sands that for several decades gave such fine results in Pennsylvania and parts of West Virginia; but the drill proved their absence, and it is now accepted by the intelligent operator that when the horizon of the Berea sand has been passed all hope of securing oil must be abandoned.

Attention was next given to the Clinton formation which had long been giving such excellent results for natural gas. Fuel in this rock was first discovered at Lancaster early in 1887, the test being a direct result of the wonderful results at Findlay and other points in northwestern Ohio. In the spring of 1887 gas was found in the Clinton at Newark and a year later at Thurston between Lancaster and Newark. Since that time the drill has been constantly at work; the result being the development of one of the finest gas fields ever known. It extends from the vicinity of Mt. Vernon, Knox County due south to Hocking County, a distance of more than sixty miles. Fuel from this field is or has been piped to such distant places as Cincinnati, Toledo, Cambridge and Mansfield. Its production is almost incredible.

But where the oil in this formation? Experience had shown that gas fields are seldom remote from oil, and the prospector jumped to the conclusion that a valuable repository of petroleum lay nearby. All that was needed in his estimation was careful search, and that he was not slow in starting. However, twelve years elapsed before a pool was found in the Clinton, and twenty years before one of really commercial proportions was secured. It may be well to state here that the gas belt lies along or near

the western margin of the Clinton sand which is the area where the sand lies highest. The principal oil pools lie farther east where the sand is found at greater depths.

OIL POOLS IN THE CLINTON SAND.

Vinton County.—This was the first to yield oil in the Clinton sand, but the production was not at all in proportion to the expenditure of time and money. In 1899 a well was completed in Jackson Township along the northern border of the county, and a small producer secured. Other wells were drilled from time to time since that year, but only seven were secured that may be rated successful. The number of dry holes has been almost equally large, and since these surround the producing territory important extensions of the latter need not be expected. The largest well had an initial flow of 70 barrels per day, but most wells were much smaller. In the summer of 1910 the seven wells combined had a daily output of less than 20 barrels. The oil is of excellent quality, having a density of about 46° Beaume, a green color in reflected light and an amber in transmitted light. The sand is porous and soft, so that the wells do not ordinarily require shooting. The "pay" often has the appearance of brown sugar, but sometimes its color is red-brown. The sand is discontinuous and of course this increases the hazard of drllling. Eastward this pool changes to gas, indicating that the rock rises in that direction, a reversal of the normal dip for Southeastern Ohio.

Bladensburg Pool.—This lies in Jackson Township in the southeastern corner of Knox County. It is situated about five miles east of the gas field and since the rocks dip southeast, lies at a greater depth. The first well was drilled in 1904, and found the sand at a depth of 2,771 feet. It began flowing oil at the approximate rate of 35 barrels a day. Four additional producers have been secured but all were small. The oil has a black color and is the heaviest found in the Clinton sand, its density being about 35° Beaumé. This pool too has been pretty well surrounded with dry holes and there is very little hope of

an extension. The sand is quite thick, 49 feet having been reported in the best producing well, but this is divided into two parts by four feet of shales. Divisions of this kind while not common are occasionally reported in different parts of the state. The wells each pump a little water but whether this belongs in the sand or has gotten in through leaky casing cannot be stated.

The Butler Pool.—This lies in Worthington Township in the southeastern corner of Richland County, and about fifteen miles north of the great gas field. In a geological sense it is the most interesting of the oil fields in the Clinton sand, though in a financial way it has been a failure. The first well was completed in the summer of 1905, and yielded gas. The closed or rock pressure reached the astonishing figure of 1,260 pounds to the square inch, making it unique among the thousands of wells drilled to that time in Ohio. The second test revealed no sand and so was a failure, but the third well found 6⅓ feet of sand and began flowing oil at the estimated rate of 200 barrels per 24 hours. Interesting to note, the oil was water white, and residents used it to some extent without explosions in lamps and lanterns. From the beginning the well yielded much gas, and after a year the production of oil had become so small that it was used exclusively for the gas. It is said that under favorable conditions it will yet flow the water-white oil.

Several other wells were secured but were smaller than the one just reported and all yielded oil of the water-white variety. Greater success was had with gas wells and a few of these are still in use. The sand is thin and patchy. According to an operator who has been familiar with the field from the start, the absence of oil or gas is generally marked by the absence of the sand also. The latter is reported to form a low dome, oil being found on the higher points and gas on the slopes, but there is reason to question the accuracy of this statement.

The Bremen Field.—This is the one important oil field in the Clinton sand. As at present developed it lies in the southeastern quarter of the state and includes parts of Rush Creek and Richland Townships of Fairfield County, and Jackson, Reading, Pike

and to a smaller extent several other townships of Perry County. It does not form one large pool at present, but several more or less disconnected ones, such as the Pleasantville, Bremen, Junction City and New Straitsville pools. Further operating may unite some of these, but the dry holes already drilled indicate that the territory is spotted and that it will hardly become one large pool.

The Bremen Field was discovered after nearly twenty years' effort, organizing and drilling, the constant encouragement being the great gas field a few miles to the west. The first actual test was made in 1896; other tests were drilled from time to time with but little encouragement until March 1907 when oil was found in a well drilled for gas about seven miles northwest of Bremen, this marking the opening of the Pleasantville pool. This result, with traces of oil on several sides of Bremen, made possible the organization of the Bremen Gas & Oil Company in May, 1907, and the active search for oil in the Clinton sand. The first test was made on Section 11 of Rush Creek Township, the territory being neither more nor less promising than other tracts leased by the company. Late in July, 1907, the drill penetrated the Clinton sand at a depth of 2,574 feet and a small volume of oil secured. The next test was located just north of Bremen, but the sand was compact and without fuel of any kind. The third test was made on section 2 of the same township and was completed in the early fall of 1907, the result being a well with an initial production of about 140 barrels a day. This was followed by a test on an adjacent farm and started flowing at the rate of 250 barrels. Naturally such results attracted wide attention and the rush began. Leases were taken at fancy prices and tests were made in all directions, but with little success to the north and west. A year later good wells were being secured to the south in the valley of Rush Creek and near the close of 1909 in the village of Bremen. One well within this village began flowing at the rate of about 500 barrels a day, making it the largest producer yet secured in the Clinton sand.

In the spring of 1909 drilling began at Junction City about

five miles east of Bremen. The Clinton sand was struck at 2,854 feet and rewarded the operator with a production of 150 barrels a day. By the middle of July, 1910, 65 wells, all of which, with a single exception, were successful, had been drilled within the corporation of 640 acres, and three strings of tools were still at work. In July, 1909, a well was completed in Coal Township near the southern border of Perry County and a small oil well secured. Since that time other tests have been made in that locality with fair results. Strenuous efforts have been made to extend the field to the east, and late in 1909 work was begun at and near Crooksville in the northeastern corner of Perry County. The Clinton sand was found at a depth of more than 3,400 feet, and yielded some oil, making them the deepest producers thus far secured in Ohio.

With the completion of wells in large numbers the production of oil increased rapidly. It amounted to more than 322,000 barrels in 1908; 799,000 in 1909; and more than 1,340,000 during the first 9 months of 1910. In May of the latter year the yield exceeded 184,000 barrels, making it the greatest for any month on record. Since that time there has been a decrease due largely to the smaller number of new wells.

Several samples of oil from this sand were collected by the writer and their composition determined by the United States Geological Survey. Commenting on these analyses Dr. David T. Day writes: "They are characteristic Appalachian oils, yielding as usual considerable amounts of gasoline and a large percentage of illuminating oil. . . . The great similarity between these oils and those of Pennsylvania and West Virginia is shown by the considerable proportion of paraffin wax and the low percentage of unsaturated hydrocarbons in the crude oil and in the burning distillate."

The Search for Oil in the Clinton Sand North and South of the Bremen Field.—The results at Bremen have stimulated drilling northward. Within the past few months successful wells have been secured in the southeastern corner of Licking County and in the adjacent part of Muskingum. Thus far the tests have

been too few to warrant more than a forecast; but producing wells scattered over parts of the three counties, Perry, Muskingum and Licking, and the demonstrated presence of the oil-bearing sand, suggest important reservoirs of oil. Doubtless the area will be thoroughly exploited. Continuing northward the drill tested the sand to the shore of Lake Erie. Gas in comparatively small volume has been secured in Ashland, Medina and Lorain Counties, but the results have not been satisfactory to the operator. Usually the wells were small, while the thin and patchy nature of the sand gave numerous dry holes. The results for oil are still less favorable, a few small producers having been secured along the eastern border of Knox County and north of the unimportant Bladensburg Pool; a show of oil at Wooster, and a small well or two in Medina County.

South of the Bremen Field a limited number of small wells have been secured in the northeast corner of Hocking County and a pool of commercial proportions may yet be found there though the prospect is not flattering. Farther south the result has been failure until northern Vinton County is reached where, as already stated, the first pool in the Clinton sand was found. Tests have been made in Jackson and Gallia Counties and in Lawrence County to the bank of the Ohio River but no oil was secured, and the prospects in that section of Ohio are unfavorable. In fact so far as the limited number of tests made can be relied on the Clinton sand is wanting in those counties that touch the Ohio River in the southern part of the state.

The Producing Sand.—While rocks of Clinton age outcrop in Southwestern Ohio in a belt extending from Preble to Adams Counties, the stratum known as the Clinton sand is nowhere found at the surface. In fact it rarely approaches 1,600 feet of the surface. It is not found farther west than the longitude of Columbus. Along its western border the sand is thin and patchy, but eastward it thickens and becomes more certain. The territory along the lake shore west of Cleveland will have to be excepted from this statement, for in that locality the sand is both thin and discontinuous. The sand has not been found farther

south than northern Jackson County but the tests south of that place have been few in number. Eastward the formation has been struck at a depth of 3,709 feet in Perry Township, Muskingum County, and at several places only a little farther west in the same county and in Perry, Morgan, Coshocton, Holmes and Wayne Counties. In all these the depth approaches 3,000 feet.

The sand varies from place to place in texture, color and to a minor extent in composition. Nowhere has it been found open-textured except in Northern Vinton County where the wells do not require shooting. Usually it is fine of grain and compact, the yield of oil being notably increased by torpedoing. The color varies from light gray to dark brown, and both may be found in the same well and produce oil. In the Bremen Field the sand averages about 30 feet in thickness, and probably no similar area known in the State exceeds this. The maximum thickness reported is 102 feet, the location being in Pleasant Township, Perry County, but thicknesses of 50 feet are uncommon for this sand anywhere in Ohio.

Structure of the Sand and its Relation to the Presence of Oil.—The general dip of the sand is southeast, but at a varying rate. Thus in the Bremen Field, the dip from the Pleasantville Pool southeast to McCuneville, a distance of 17 miles, averages 57 feet to the mile, the maximum being 97 feet and the minimum 43 feet. From Lancaster due east to the Lefever well near New Lexington the average dip is 57 feet per mile with a maximum of 63 and a minimum of 55 feet. Measurements on adjacent wells show occasional reversal of dips so that the sand may be described as gently rolling, but with a prevailing southeasterly dip. From what has been stated it is clear that in the one really important oil field in the Clinton sand anticlines do not form the principal structural feature.

In Vinton County the gas territory lies east of the oil, indicating a reversal of dip, that is the sand rises to the east instead of dipping in that direction. Records for northern Ohio indicate the sand dipping gently to the south and more rapidly to the east.

Salt water is usually considered an important factor in determining the position of oil, the latter resting on the surface of the water; but in this respect the Bremen Field is unique for it is generally agreed that when the sand in any locality is first penetrated it is free from water.

The conditions in the Bremen Field then are a sandstone, without water, dipping sharply to the east and south with vast reservoirs of gas in the higher parts, that is along or near the western margin of the formation, with more or less disconnected pools of oil farther down the dip or slope of the rock. Manifestly something must hold the oil in position for otherwise it would creep down the slope and reach depths unattainable by the drill. Minor folds in the sand give basin structures and in these the oil has collected.

Commonly the closed or rock pressure of gas wells is ascribed to hydrostatic action, but manifestly this does not apply in the Clinton sand of Ohio where the pressure originally varied from 700 to 1,260 pounds to the square inch, and yet the gas rock, is free from water. It does not appear that hydrostatic action is even a factor in producing the rock pressure in this territory.

Stratigraphical Position of the Clinton Sand.—When gas was discovered in this formation at Lancaster in 1887, Orton supposed the producing rock to be limestone, and knowing its general position with reference to the great Devonian and Silurian limestones called it the Clinton.[1] "The lower surface of the limestone," he says, "does not come out very distinctly in the records that are accessible, but a red shale was struck at 1,810 feet, interbedded with which were hard calcareous bands that bruised the bit out of gauge like sandstone. . . . There is some question as to the geological source of the gas, whether derived from the Clinton or Medina horizon, with the probabilities greatly in favor of the former. Both contain red shales." After these lines had been written the well was drilled deeper and Dr. Orton thus commented on the data: "The later records of this well and of two subsequently drilled are full of interest. Drilling was continued

[1] Orton, Edward, Geol. Surv. of Ohio, Vol. VI., p. 383.

in the first well for a comparatively short distance below the gas vein, but the distance proved long enough to identify the horizon beyond all question. A bed of red rock was the most conspicuous element in the new portion of the section, and this, on examination, proved to be the iron ore of the Clinton horizon, the most definitely characterized bed in the whole column of Ohio. It was thus learned that the gas in question is derived from a bed of crystalline light colored limestone, included between two beds of red rock, all of which are of Clinton age." Dr. Orton then gives an analysis of what was represented to be the gas rock and shows it a limestone that agrees in composition with the Clinton. Two years later (1890) he published the First Annual Report (Third Organization) and there speaks of the gas rock as "a bed of sharp sand,"[1] but adds that some maintain that the original identification of the rock was the correct one. Shortly after this time the multiplicity of wells settled the point, and all spoke of the gas rock as a sandstone.

The stratigraphical position of the sand remains, however, unsettled though it is practically always called the Clinton. In considering this point it may be well to begin with the Devonian and Silurian limestones, known among drillers as the "Big Lime" and whose base is represented by the Clinton limestone. Near Bremen these aggregate about 800 feet, and are divided as follows on the basis of chemical and physical properties as shown in an extensive set of drillings.

COLUMBUS LIMESTONE. 50 feet. Calcareous, gray color.

MONROE LIMESTONE. 275 feet. Magnesian. Dark gray color, contrasting in this respect sharply with the Columbus limestone. Some gypsum at from 125 to 200 feet in the formation.

NIAGARA LIMESTONE. 360 feet. Magnesian. Light gray color changing to brown in lower part. Drillings fine, resembling sand grains. These drillings in size and color make a sharp contrast with those of the Monroe limestone.

CLINTON LIMESTONE. 95 feet. Calcareous. Dark gray at top, changing to various tints below with slate color at base.

[1] Orton, Edward, Geol. Surv. of Ohio, First Ann. Rept., p. 230.

In the gas fields southwest of Bremen a bed of sand is occasionally found in the "Big Lime" and this may yield a good flow of gas. The stratigraphical placement of this formation has not been definitely determined but it seems to be in the Niagara limestone rather than in the overlying Monroe which, as is well known, contains a layer of sand in northern Ohio. Northward from the Bremen Field the "Big Lime" thickens and from Wooster to Lake Erie contains salt. At Elyria, Lorain County, the formations aggregate 1,230 feet and at Cleveland they are notably greater. This thickening in the northeastern corner of the state is due in part to the Salina formation, which lies as a wedge between the Niagara and Monroe with the thicker portion of the wedge to the northeast. How far west and south it extends has not been determined, but rock salt has not been reported farther west than Elyria nor farther south than Wooster. South of the Bremen Field the "Big Lime" thins slowly, measuring less than 600 feet at Ironton on the bank of the Ohio River.

In Western Ohio the Clinton formation according to Dr. A. F. Foerste[1] "Consists of an almost continuous section of limestone with only a few inches of intercalated clay at the top" and "does not exceed 20 feet in thickness."

"The underlying Ordovician section," he says, "consists of clay, frequently 50 feet thick, containing very few fossils, among these *Hebertella sinuata, Tetradium minus, Labechia ohioensis, Platystrophia acutiluata* var., *Eurychilina striatomarginata, Leperditia calcigena, Dawsonoceras hammelli* and other forms found in the upper part of the Richmond section. There is nothing Silurian about these forms." It will be noted from this that in Western Ohio, according to Foerste, the Clinton terminates at the base of the limestone.

Overlying the Clinton limestone there are, according to the same authority from "5 to 7 feet of dense white limestone, overlaid by 20 feet of limestone layers, about 3 to 4 inches thick, interbedded with clay layers, 1 to 3 inches thick. This interbedded limestone and clay section corresponds stratigraphically

[1] Personal communication.

with the much thicker continuous clay section of Highland and Adams counties, in the southern part of the state, and in Kentucky. Overlying the Niagara shale section, the dolomitic Springfield and Yellow Springs limestones come in."

In the Bremen Field and in central Ohio generally the shales lying in the lower part of the Niagara are wanting, and as has already been stated, the formations from the top of the Devonian limestone to the base of the Clinton consist of limestones only. The oil and gas rock in this territory known as the Clinton sand lies from 90 to 180 feet below the base of the Clinton limestone. This interval increases to the southeast, having been reported at 335 feet in the western part of Morgan County. It measures 200 feet in Jackson County, the southernmost point from which the sand has been reported, but only 15 feet near Berea in the northern part of the state. The latter figure, however, appears to be somewhat unusual for in the adjoining county (Lorain) to the west, intervals of 67 and 127 feet are reported. Data from Medina, Ashland and Wayne Counties show intervals of about 100 feet.

This interval is occupied by shales of various colors, and occasional thin calcareous layers known as shells among the drillers. These vary somewhat in color and other characters from place to place. In the gas belt about eight miles south of Lancaster samples of drillings of this formation were collected with the following result:

	Feet.
Base of the "Big Lime."	
Shales, light chocolate color; some lime	36
Shales, green and chocolate colors, the latter fossiliferous; some lime	31
Shales, green and chocolate colors, much lime	37
Top of Clinton sand.	

Quite commonly a few feet of red shales overlie the sand in the Bremen Field, and a similar bed is generally reported beneath the sand where the latter is found.

These facts make clear that the oil and gas sand lies imbedded in shales from about 100 to 200 feet below the Clinton lime-

stone, but where are these shales with the imbedded sandstone to be placed in the geological column? If we follow the section at Dayton, they constitute the top of the Ordovician. May it not be that they represent in part at least the Medina of the Niagara Gorge where according to Grabau the section is as follows:[1]

Rochester shale.			
Clinton limestone and shales.	Limestone, upper member		11 ft.
	Limestone, lower member		14½–15 ft.
	Shales, olive green, grayish to purplish gray		6 ft.
Medina sandstone and shales.	Upper shales and sandstones.	Quartzose sandstone, light color	7½ ft.
		Sandstone, massive reddish to gray	12–15 ft.
		Sandstone, thin bedded, compact and solid, reddish or gray mottled with red, some shales	35–40 ft.
		Shales, gray and greenish gray	6 ft.
		Sandstone and sandy shales	5 ft.
		Shales, gray	25 ft.
	Quartzose sandstone, gray		25 ft.
	Medina shales, red. Upper beds only shown.		

The quartzose sandstone near the base of the above section resembles the Clinton sand of Ohio and it occupies a similar position with reference to the Clinton limestone. The rocks between the sandstone and limestone have many points in common, the chief difference being in the large quantity of sand in the Niagara section, but in the writer's judgment this is a matter of small importance viewed from the stratigraphical standpoint.

PROBABLE EASTERN EXTENSION OF THE OIL TERRITORY.

Wells drilled in the northeastern corner of Perry County, the western part of Muskingum, the southeastern township of Licking and yielding oil in commercial quantity, indicate that important additions to the producing territory may be expected in

[1] Grabau, A. W., Bull. N. Y. State Mus., No. 45, Vol. 9, pp. 87–102.

that area of Ohio. Farther north the situation is not quite so promising, but the show of oil at Wooster and one or more small producing oil wells in Medina County indicate that pools of commercial size may yet be found. The situation in southern Ohio is less favorable, the sand appearing to be more uncertain, but possibly when the drill has moved farther east where depths approaching 3,500 feet are necessary, conditions may improve.

It is important to note that the sand dips much more rapidly to the east than the well known Berea sand, for the Ohio shales and "Big lime" which lie between these two sands, are wedge-shaped with the apex in central Ohio. It is this condition that carries the Clinton sand to such depths that it is not accessible to the drill in eastern Ohio.

DIFFERENTIATION PRODUCTS IN QUARTZ DIABASE MASSES OF THE SILVER FIELDS OF NIPISSING, ONTARIO.

REGINALD E. HORE.

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Discussing in this journal[1] the origin of the cobalt-silver ores of Nipissing, Ontario, the writer gave reasons for believing that the ores were originally constituents of a magma which had a composition near that of quartz diabase. It was pointed out that the mode of occurrence of certain salic and mineralized portions of the diabase is that which would result from a process of differentiation during cooling. The nature of the fissures and degree of stability of the minerals in the surrounding rocks were suggested to be the chief factors controlling the nature of the deposits formed when the highly differentiated mineral bearing solutions from the diabase magma escaped and became mixed with the ground water. The summary of the paper was as follows:

It has been shown that cobalt ores have been deposited from solutions which followed the formation of veins of aplite in the diabase. Since in all the silver deposits in the district the silver minerals are intimately associated with cobalt minerals, the silver is believed to have the same origin.

It is suggested that the metallic sulphides and arsenides have concentrated from the diabase magma by extreme differentiation. The Keewatin igneous rocks have assisted in the ore deposition on account of their content of calcite and unstable minerals. The Huronian sediments are composed for the most part of stable minerals with very little calcite, and their chief function has been that of a recipient for the ores. If these conclusions are correct, we may expect to find similar ore deposits where the diabase sills are associated with Keewatin igneous rocks, and especially valuable deposits where Huronian sediments are also present.

[1] R. E. Hore, "Origin of Cobalt-Silver Ores of Northern Ontario," Vol. III., No. 7, 1908, pp. 599–610.

The term "differentiation," here used in the general sense of writers on the theory of solutions, was misinterpreted by some who use it in a more special sense when discussing ore deposits, and it was therefore found advisable to describe[2] the supposed process in more detail as follows:

There has been apparently no igneous activity since the complete solidification of the diabase magma. It is suggested, therefore, that the silver and cobalt were present in that hot solution, which was composed largely of the constituents of silicates, etc., with water vapour and other gases. When, on cooling, the greater part of the magma had solidified, the minor still fluid portion contained a higher percentage of salic components (forming feldspars and quartz) and of water vapour, carbon dioxide, silver, etc. Such differentiated fluid materials were tapped by the opening of fissures in the cooling solid mass. According to local conditions of temperature and pressure and the mobility of the materials, they escaped through or were deposited in those fissures. The feldspars were apparently deposited, for the most part, at high temperature in the diabase fissures. Other constitutents, in some cases, escaped into the surrounding rocks. Some deposition was doubtless caused simply by loss of heat and relief of pressure, some by mixing with the ground waters. According to the character of the rocks penetrated by the metalliferous solutions, and the nature of the fissures in them, the ores were there more or less concentrated.

For such differentiation of a rock magma, the writer has elsewhere called attention to the possibility of the failure of the constituents of the solution to mix in all proportions. Since, however, similar end products might be produced whether separation into two solutions took place or not, the relative solubilities and miscibilities need not here be discussed.

Three field seasons have passed since the article in this journal on the origin of the silver ores was written, and many new discoveries have been made. In reading the above summary, therefore, it is interesting to note that without exception these deposits occur in or near diabase masses, that of the mines in the younger camps that are on a shipping basis are all in localities where the diabase intrudes Keewatin greenstones, and that by far the most productive of these deposits is one in the Huronian sediments.

[2] *Canadian Mining Journal*, April 15, 1909.

There seems little reason to doubt, therefore, that while there are a great many features connected with the silver deposits which are not yet understood, the hypothesis here outlined is still tenable.

That the association of the deposits with the diabase masses is a result of common origin is especially evident, and recognition of this fact has resulted in more careful investigation of these rocks. It might have been expected that they would be found to have unusual characters; but study has shown that they are in chemical and mineralogical composition the most common type of quartz-diabase. Very similar types are of widespread occurrence in North America, and almost identical ones from South America and England have been described. Aside from the actual ores themselves, there is as yet little to distinguish the quartz-diabase of Nipissing from those of other regions. More refined methods of investigation may bring out some characteristic features, and in the meantime it is of interest to assemble the available data. Table I shows the available analyses, and the chief mineral constituents of the rocks analyzed.

The aplitic differentiation products of quartz-diabase in James Township, and their connection with cobalt and silver ores, was described by Dr. A. E. Barlow[1] in a paper which appeared at the same time as that of the present writer. He also gave arguments in favor of a genetic connection of the ores with the diabase. Mr. J. B. Tyrrell, in discussing the two papers, is of the same opinion. The influence of the intruded rocks has not been discussed by either of these gentlemen, nor by any of the writers since the publication of the views of Professor Van Hise and Dr. Miller, which have already been referred to.

In the fall of 1908, the writer interested Messrs N. L. Bowen and J. A. Dawson in the examination of some of the rocks from the Nipissing silver camps. Mr. Bowen analyzed a number of

[1] A. E. Barlow, "Origin of Silver of James Twp.," *Jour. Can. Min. Inst.*, Vol. XI., 1908, pp. 256–273.

specimens of the igneous types and presented his results in paper at the 1909 meeting of the Canadian Mining Institute. Mr. Dawson investigated the associated sediments, but has not yet published his results. I have to thank him for a hitherto unpublished analysis of Huronian shale given below.

Recently the writer presented a petrographic description[1] of the diabase and its differentiation phases. This is necessarily incomplete, but gives the most prominent features as they appear after an examination continued for the greater part of four field seasons, and including occurrences in most of those localities in Nipissing in which silver and cobalt minerals have been found.

Quite recently there have appeared two papers on the same subject. One of these is by Mr. W. H. Collins,[2] of the Canadian Geological Survey, who spent the field seasons of 1908 and 1909 in the Gowganda and Montreal River districts. The second is by Mr. N. L. Bowen,[3] who in 1909 was working for the Ontario Bureau of Mines in the vicinity of Gowganda.

That the composition and modes of occurrence of the diabase masses observed by these gentlemen are similar to those observed by the writer, is evident from their descriptions. They have each, however, found locally developed some different modes of occurrence which have influenced their views on the origin of what I have called differentiation products. With regard to the form of the diabase masses both these writers emphasize the statement that all are sills or dykes. While this holds true for most cases it should be remarked however that many of the masses are not simple sills but have rather the character of asymmetric laccolites, and that other masses show no sheet-like form and in surface exposures more nearly resemble stocks.

Finding that in certain places the more siliceous albitic red rock or granophyre is at the contact with overlying shales, Mr. Bowen

[1] R. E. Hore, "Diabase of the Cobalt District, Ontario," *Jour. Geol.*, Vol. XVIII., No. 3, April–May, 1910.

[2] W. H. Collins, "Quartz Diabases of Nipissing District," Economic Geology, Vol. V., No. 6, Sept., 1910, pp. 538–550.

[3] "Diabase and Granophyre of the Gowganda Lake District, Ontario," *Journal of Geology*, Vol. XVIII., No. 7, Oct.–Nov., 1910, pp. 658–674.

No.	Locality.	Rock Name.	Chief Mineral Constituents.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO
1	Cross Lake, Cobalt, Ont.....	Olivine, diabase.	Calcic plagioclase, olivine, pyroxene, iron ores.	45.20	19.08	3.64	14.64	4.98	7.89
2	Cross Lake, Cobalt, Ont.....	Diabase.	Labradorite, augite, biotite, iron ores.	49.84	18.94	1.51	6.40	7.39	10.32
3	Violet Mine, Cobalt, Ont.....			48.06	18.23	—	—	7.80	11.55
4	O'Brien Mine, Cobalt, Ont.....	Quartz-diabase.	Calcic plagioclase, augite, rhombic pyroxene, biotite, ilmenite and magnetite, quartz (in micropegmatite).	50.12	15.70	1.42	6.89	9.50	11.30
5	Kerr Lake Mine, Cobalt, Ont.....			50.80	19.42	0.97	6.67	5.78	12.68
6	Silver Bar Mine, Cobalt, Ont.....			50.69	16.11	0.70	7.05	8.20	12.09
7	University Mine, Cobalt, Ont.....			50.48	17.03	1.25	7.81	9.32	10.96
8	Bartlett Mine, Gowganda, Ont. .	Quartz-gabbro or (granophyric diabase), or (micropegmatitic diabase) No. 8 is weathered and contains calcite.	Uralitic pyroxenes, calcic plagioclase, sodic plagioclase intergrown with quartz (micropegmatite), biotite, ilmenite and magnetite.	48.41	19.29	1.33	8.27	4.70	4.93
9	Pense Twp., Nipissing, Ont. . .			52.54	15.14	0.85	10.73	5.22	6.92
10	James Twp., Nipissing, Ont.			52.25	17.97	0.81	8.89	6.46	7.27
11	Lost Lake, Gowganda, Ont. .	Granophyre.	Sodic plagioclase, hornblende, quartz.	62.54	14.79	—	8.49	2.08	1.49
12	University, Mine, Cobalt, Ont.....	Aplitic soda granite.	Albite, quartz, calcite, chlorite, titanite.	72.33	12.99	none	2.50	0.97	1.73
13	University Mine, Cobalt, Ont.....			73.07	14.88	0.04	2.93	1.30	0.66
14	James Twp., Nipissing, Ont.			78.28	12.00	—	1.19	0.37	0.29
15	James Twp. Nipissing, Ont. . .			58.84	11.24	—	0.47	0.35	12.19

CHEMICAL COMPOSITION

No.	Rock Name.	Locality.	Analyst.	SiO_2.	Al_2O_3.
1	Diabase	University Mine, Cobalt, Ont.	R. E. Hore	50.48	17.03
2	Diabase	Silver Bar Mine, Cobalt, Ont	R. E. Hore	50.69	16.11
3	Aplitic Soda-granite. (Intrudes	University Mine, Cobalt, Ont. No. 1)	R. E. Hore	73.07	14.88
4	(Intruded by Shale.	No. 1.) Giroux Lake, Cobalt, Ont.	J. A. Dawson	55.97	19.35

TABLE I.

tz-Diabase, Quartz-Gabbro, Granophyre, and Aplitic Soda Granite from Nipissing Silver Fields.

)	CaO	Na_2O	K_2O	H_2O+	H_2O-	CO_2	TiO_2	S	P_2O_5	BaO	H_2O	H_2O and CO_2	NiO and CoO	FeO and Fe_2O_3	Sum.	Collector.	Occurrence Described by	Micr Exa
3	7.89	3.32	1.08	—	—	—	—	—	—	—	n.d.	—	—	—	99.83	W. G. Miller	W. G. Miller	C. W
)	10.32	1.99	1.28	—	—	—	—	—	—	—	2.57	—	—	—	100.24	W. G. Miller	W. G. Miller	C. W
)	11.55	1.87	0.27	—	—	—	—	—	—	—	3.54	—	—	9.57	100.89	?	W. G. Miller	J.
)	11.30	2.91	1.07	1.03	0.21	—	0.55	0.14	p.n.d.	none	—	—	—	—	100.84	R. E. Hore	R. E. Hore	R. N.
3	12.68	1.60	0.37	0.86	0.25	—	0.43	—	p.n.d.	—	—	—	0.01	—	99.84	R. E. Hore	R. E. Hore	R.
)	12.09	1.78	0.78	1.65	0.16	—	0.53	0.07	p.n.d.	—	—	—	0.11	—	99.82	R. E. Hore	R. E. Hore	R.
2	10.96	1.95	0.24	0.82	0.22	—	p.n.d.	—	p.n.d.	—	—	—	0.04	—	100.12	R. E. Hore	R. E. Hore	R.
)	4.93	5.92	0.41	—	—	2.41	0.88	—	p.n.d.	—	3.99	—	—	—	100.29	J. A. Dawson	J. A. Dawson	R. N.
4	6.92	5.46	1.42	—	—	—	1.00	—	p.n.d.	—	1.76	—	—	—	101.05	R. E. Hore	R. E. Hore	R. N.
5	7.27	3.61	1.71	1.80	0.04	—	p.n.d.	—	p.n.d.	—	—	—	—	—	100.81	R. E. Hore	R. E. Hore	R.
3	1.49	6.27	1.12	—	—	—	—	—	—	—	—	3.51	—	—	100.29	N. L. Bowen	N. L. Bowen	N.
7	1.73	7.60	none	—	—	1.00	0.74	—	p.n.d.	—	1.09	—	—	—	100.95	R. E. Hore	R. E. Hore	R. N.
)	0.66	6.17	0.46	—	—	—	0.41	—	p.n.d.	—	0.90	—	none	—	100.82	R. E. Hore	R. E. Hore	R.
7	0.29	6.89	none	—	—	none	0.34	—	p.n.d.	—	0.61	—	—	—	99.97	J. A. Dawson	J. A. Dawson	N. R.
5	12.19	6.91	none	—	—	9.84	0.26	0.13	p.n.d.	—	0.40	—	—	—	100.61	H. T. White	R. E. Hore	N. R.

TABLE II.

position of an Aplite Dyke and the Associated Diabase and Shale.

$_2$.	Al_2O_3.	Fe_2O_3.	FeO	MgO.	CaO.	Na_2O.	K_2O.	H_2O+.	H_2O-	CO_2.	TiO_2.	NiO and CoO	P_2O_5.	S.	Ba.	Sum.
48	17.03	1.25	7.81	9.32	10.96	1.95	0.24	0.82	0.22	—	p.n.d.	0.04	—	—	—	100.12
59	16.11	0.70	7.05	8.20	12.09	1.78	0.78	1.65	0.16	—	0.53	0.11	—	0.07	—	99.82
07	14.88	0.04	2.93	1.30	0.66	6.17	0.46	(0.	90)	—	0.41	none	—	—	—	100.82
07	19.35	1.95	7.07	3.34	0.74	2.73	5.08	2.84	0.02	0.02	0.74	—	0.26	0.04	none	100.25

llector.	Occurrence Described by	Microscopically Examined by	Analyzed by
G. Miller	W. G. Miller	C. W. Knight	A. G. Burrows
G. Miller	W. G. Miller	C. W. Knight	A. G. Burrows
?	W. G. Miller	J. O. Handy	J. O. Handy
E. Hore	R. E. Hore	R. E. Hore N. L. Bowen	N. L. Bowen
E. Hore	R. E. Hore	R. E. Hore	R. E. Hore
E. Hore	R. E. Hore	R. E. Hore	R. E. Hore
E. Hore	R. E. Hore	R. E. Hore	R. E. Hore
. Dawson	J. A. Dawson	R. E. Hore N. L. Bowen	N. L. Bowen
E. Hore	R. E. Hore	R. E. Hore N. L. Bowen	N. L. Bowen
E. Hore	R. E. Hore	R. E. Hore	R. E. Hore
L. Bowen	N. L. Bowen	N. L. Bowen	N. L. Turner (SiO_2 by N. L. Bowen)
E. Hore	R. E. Hore	R. E. Hore N. L. Bowen	N. L. Bowen
E. Hore	R. E. Hore	R. E. Hore	R. E. Hore
. Dawson	J. A. Dawson	N. L. Bowen R. E. Hore	N. L. Bowen
T. White	R. E. Hore	N. L. Bowen R. E. Hore	N. L. Bowen

Sum.
00.12
99.82
00.82
00.25

studied the influence of the sediments in the formation of such a facies of the igneous rock. He concludes that the formation is due in the first place to a kind of differentiation is which the solutions escaping after most of the diabase had solidified, are "soda-bearing carbonate waters." His conclusion on this point is evidently similar to that of the writer as expressed above in the words, "when on cooling, the greater part of the magma had solidified, the minor still fluid portion contained a higher percentage of salic components (forming feldspars and quartz) and of water vapour, carbon dioxide, etc." His second conclusion, however, that such differentiation is not sufficient to produce granophyre but only to contribute to its formation by inducing alteration of the slaty sediments can be objected to both from a consideration of the theory of solutions and of facts observed in the field. The statement that the albitic rocks are especially characteristic of places where diabase intrudes shales, cannot without restriction be applied to the Nipissing silver field. There are, in the Temagami Reserve, numerous large masses of the red sodic facies of the diabase which are not near any argillaceous sediments. Some of the granophyric diabases are several miles from any exposed shale or slates and in localities where there is no good reason to believe that such rocks are or were present. The granophyric diabase which has developed between the slate fragments of the contact breccia at Foot Lake is evidently very similar to those which have been developed far from any such contacts.

It should also be noted that while differentiation in the dykes in Nipissing is not marked, there are other localities in which dykes of quartz diabase are in their central parts much higher in silica and alkalies than on the margin. The central parts of such dykes are almost identical with the micropegmatitic or granophyric diabases of Nipissing. Numerous occurrences of quartz-diabase (probably Keweenawan) dykes showing such characters were found in Rainy Lake District, Ontario by Professor A. C. Lawson, and in Michigan by Professor A. C. Lane.

In considering the effect of the igneous intrusives on the

sediments, the writer remarked on the very narrow zone of evident metamorphism. Both Mr. Bowen and Mr. Collins make the same statement, and it is evidently then a characteristic phenomenon. Mr. Collins mentions that he has found blocks of the intruded strata, which were evidently "torn off and enclosed by the fluid diabase, but as they always retain their angular outlines, there appears to have been no assimilative action." The writer also has found no evidence of extensive absorption of intruded rocks. Evidently the intruded rocks had some effect on the solidification of the magma; but the effect was slight, and not in a great degree dependent on the type of rock intruded. From the study of a very large number of contacts, it seems almost certain that when the diabase magma came to rest it was at a temperature very little above that of freezing. Before any great amount of heat was given off to the enclosing rocks, the fluid magma began to solidify, and became in a sense self insulated before any extensive fusing or overhead stoping took place.

In comparing the composition of the different facies of igneous rocks with that of intruded sediments, the analyses of Cobalt rocks in Table II are of interest. On the property of the University and Silver Bar Mines, and near the shore of Giroux Lake, there are outcrops of grey quartz diabase (1 and 2) traversed by a 50-foot-wide dike of aplitic soda granite (3). Specimen (1) was taken about 25 feet south of the aplite and specimen (2) several hundred feet farther west, and only a few feet above underlying shales. Workings in the mines near by show that the sediments under the diabase are dark shales, and exposures further west show similar shales (4). The rocks which originally overlaid the diabase have been completely removed by erosion. The specimen of shales (4) was taken from an island in the lake about 100 feet west of the diabase. The interval, including the immediate contact, is under water. Comparison of the quantities of the constituents in the three rocks can scarcely lead to the conclusion that the sodic aplite has been developed by the effect of the diabase on the shale, but

rather to the conclusion that the composition of the aplite is quite independent of the composition of the intruded sediments. It is a remarkable fact that not in any one constituent element is the quantity in the aplite intermediate between that in the diabase and that in the intruded shale. The rocks, which east of Giroux Lake overlie the diabase sill, are basic Kewatin greenstones and chemical composition differ from the diabase chiefly in the products of very extensive weathering.

The four specimens were collected by the writer, the analyses were made by the methods recommended by H. S. Washington.

In connection with the differentiation process, Mr. Collins remarks that "the diabasic magma behaves as a homogeneous mixture or, more probably, a mutual solution of two chemically and mineralogically definite rock species, designated diabase and aplite," of which diabase crystallized somewhat in advance of aplite, and "simultaneously they commenced to segregate from each other." He considers the quartz-diabase to be one of a confusing variety of hybrid rock forms resulting from incomplete segregation. The plausibility of this supposition he supports by the discussion of a number of optical mineral analyses of the rocks. It should be remarked, however, that the assumptions necessary in such a hypothesis are open to objection.

If such segregation takes place while constituents are in the liquid form it would be necessary to attribute to rock magmas characters very different from those solutions which have been carefully studied, and to reinterpret what is known concerning the miscibility of fused silicates. It would be equivalent to stating, for instance, that molten sodic plagioclases will mix with molten calcic plagioclase in a very limited degree, if at all. Such a statement is contrary to the interpretation put on facts which have been determined by experimental synthesis, and by examination of the end products formed in nature. If, as is generally believed, the common silicates are miscible in all proportions, then segregation results from differentiation during crystallization.

While considerable has been written concerning the formation of aplitic veins and micropegmatite by differentiation, the

possible formation of such rocks by secondary processes has been but slightly discussed in the papers above mentioned. This has probably been the case, not because there is no evidence of secondary origin, but rather, because that which points to primary origin seems to outweigh the other. It may be of interest, however, to consider some observations which suggest the possible importance of secondary formation.

The minerals of the aplitic veins and of the micropegmatite are of species which are often found in occurrences of undoubtedly secondary nature. Quartz is everywhere recognized as a common secondary as well as a common primary constituent of rocks. Feldspars are less often regarded as common secondary types; but they are by no means uncommon. Pink feldspars are quite frequently found filling amygdules in the Keweenawan volcanic rocks of Lake Superior. These feldspars have evidently been formed, like the chlorite, quartz and zeolites, by the weathering of the igneous rocks, and the rocks have a composition not far from that of the diabase of Nipissing. There is, moreover, in the literature abundant evidence that sodic feldspars are a characteristic product of the weathering of soda-lime feldspars, and that under the same conditions calcite is also commonly formed. On the other hand it is of interest to note that while secondary feldspars and quartz are very abundant in the Keweenawan extrusives, micropegmatitic intergrowths, as Dr. Lane[1] has pointed out, do not occur in those rocks. It is fair to deduce therefore that the micropegmatite in the Nipissing quartz diabase is an original structure and not the result of weathering. Other arguments leading to the conclusion that the micropegmatite of the Michigan quartz diabases is primary have been summed up by Dr. Lane and may be applied as well to that of Nipissing. Chlorite, the fourth chief constituent of the aplites, is not only a common secondary product, but in the form in which it here occurs it has never been found as a primary constituent. The fifth mineral, titanite, is also found as a sec-

[1] Dr. A. C. Lane, "Diabases (Keweenawan) intrusive in the Huronian," Mich. Geol. Surv., Vol. VI., Part I., pp. 219–266.

ondary product from the alteration of titaniferous iron ores, and the diabase always contains such.

Another feature of the diabase masses which suggests the secondary origin of the aplites is the similar occurrence of small veins of epidosite. Such veins, made up chiefly of granular epidote, quartz, and a dark green hornblende, have been found in several localities in which there are cobalt minerals in the diabase. Such rocks in other localities are regarded as secondary products, and there is no special reason for classing these as primary. Some of the aplite veins are very similar to these epidosites in their mode of occurrence, and some of the aplites contain a few small grains of epidote. Many of the aplite veins, however, show marginal characters typical of contemporaneous veins, and all are formed of minerals similar to those which were last to crystallize in the quartz-diabase.

Summarily then, there are some portions of the diabase masses which may have been formed, long after the complete solidification of the magma, by weathering and redeposition. These same portions may however represent the end products in a process of differentiation, and since this hypothesis has the added advantage of correlating a number of other observed facts it is to be preferred.

THE IRON FORMATION OF THE CUYUNA RANGE.

FRANCIS S. ADAMS.

PART II.

THE DEERWOOD IRON FORMATION.

DISTRIBUTION.

The "Deerwood formation" is the name recently given by Leith to the iron-bearing formation of the Cuyuna Range and the formation will be so termed in this article. As a whole it consists of lenses of iron formation distributed through the great slate formation, differing from the well-defined iron formations of the other Upper Huronian iron ranges of the Lake Superior region with the exception of the Crystal Falls and Florence district. The Mesabi formation of the Mesabi range and the Ironwood formation of the Penokee district for example, are thick continuous sedimentary deposits overlain by slate and underlain by quartzite, with the lines of demarkation fairly well defined. The Deerwood formation is not a continuous formation but a series of detached lenses thickly scattered through the slate member at different horizons. These lenses are nearly parallel, overlap each other, and are interbedded with the slate formation. The formation shows all the gradations from the original cherty iron carbonate rock to the resultant ores, and phases resulting from the partial and complete anamorphism of the original and altered phases. The distinct types may be grouped as follows: cherty iron carbonates, ferruginous cherts, hard and soft ores, amphibole magnetite rock, paint rock and highly ferruginous slates.

The distribution of the iron formation is indicated by a series of parallel magnetic belts and by the drilling so far accomplished. Nearly 2,000 holes have been drilled on the entire range and two shafts have been sunk into the formation. So far it has been exposed by drilling in two separate areas of the Cuyuna district,

known as the north and south ranges. The formation on the south range, consisting of a series of nearly parallel, elongated lenses, forming as a whole a long narrow belt, extends in a southwesterly direction. The eastern extremity of the explored portion of the south range is in township 48 N., R. 26 W.; southwest from this, the Deerwood formation has been proved in townships 47–26, 47–27, 46–28, 46–29, 45–29, 45–30, 44–30, 44–31, 43–31, 43–32, and 133–32. The strike of these parallel belts or lenses of formation is northeast by east. On the north range lying parallel to the south range and four to five miles to the north of it, the formation has so far been proved in townships 47–28, 47–29 and 46–29. Here also the formation consists of a series of nearly parallel overlapping lenses having the same general strike as those of the south range. These lenses are more scattered and cover a wider area than the belt-like series of the south range. The lenses of the Deerwood formation are also marked by parallel belts of magnetic attraction, as shown on sketch map accompanying this report. A heavy drift mantle varying in depth from 50 to 390 feet covers the entire district.

The magnetic character of the formation as a whole is responsible for the belts of magnetic attraction which outline the distribution. The magnetic attraction varies widely, in some places giving maximum dip needle readings of 85° to 88° from the horizontal, while other parts of the iron formation exert little or no magnetic attraction. Contrary to earlier suppositions the ore bodies are not those portions of the formation where there is the strongest attraction. The ore, while somewhat magnetic, exerts a comparatively weak attraction as compared with the amphibole magnetite rock associated with it. Of course drilling in the immediate vicinity of a strong line of attraction generally exposes ore, because of the close association of the ore and amphibole magnetite rock; but such a line should be looked upon as showing the presence of amphibole magnetite rock while the ore is likely to be found on one or both sides.

This amphibole magnetite rock is a very persistent phase of the Deerwood formation and is found in close association with

nearly all of the proved ore bodies. It commonly forms the footwall of the ore and often occurs interbedded with the ore itself or immediately adjacent to the ore on both the hanging and foot-wall sides. This amphibole magnetite rock was produced by partial anamorphism of the original iron formation due to heat and pressure developed by contact with intrusives and by acute folding. This accounts for its widespread distribution throughout the entire formation.

Structural Relations of the Ore Deposits.

Gradation Laterally and at Depth into Other Phases of the Iron Formation.

Generally speaking the ore bodies of the Cuyuna occur in the upper portions of steeply dipping lenses of iron formation and also in the lower portions of such lenses where certain structural

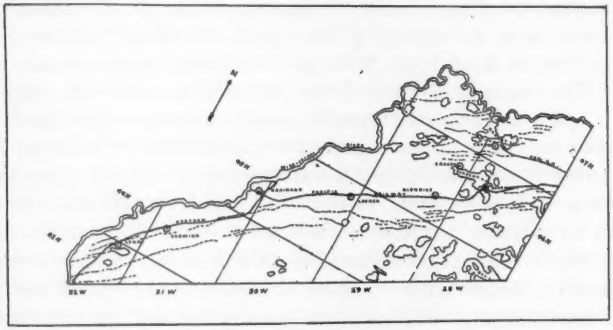
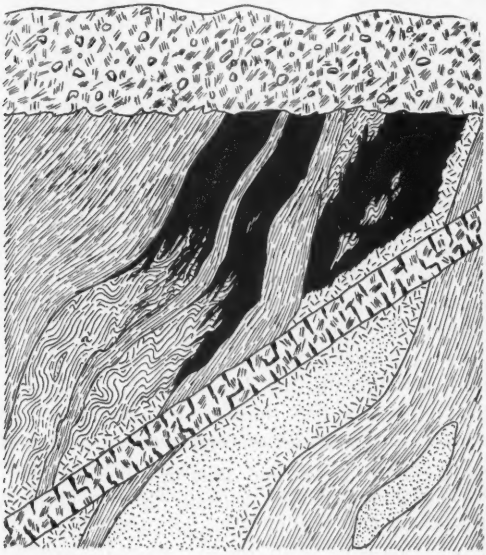


Fig. 8. Map of the Cuyuna Iron Range. The dotted lines show magnetic belts.

features allow of a considerable flow of meteoric waters to the deeper levels.

Where the entire upper portion of lenses of iron formation have been concentrated to ore, the dip of the resulting ore bodies will be that of the lenses of iron formation. These lenses dip steeply from 50° to vertical. While the pod-shaped lenses of

iron formation have fairly uniform dips and strikes, the actual ore bodies concentrated within them represent those portions of the lenses most easily penetrated by the ground waters and hence are less regular, as the meteoric waters flowing through a lens of



1. Ore.
2. Ferruginous chert.
3. Cherty iron carbonate.
4. Amphibole magnetite.
5. Slate.
6. Dike.

FIG. 9. Ideal cross section showing types of ore deposits.

iron formation have left behind them concentrated ore along the channels of heaviest flow and wherever ponding has taken place Usually the greater part of the upper portion of a lens has been easily penetrated by the waters and has thus become ore.

The ore bodies vary from a few feet to two or three hundred in width and from fifty feet to half a mile or more in length.

Reference to the ideal cross section (Fig. 348) illustrates the typical concentration to ore in an iron formation lens of the Deerwood formation. Following the dip of a lens of iron formation, the ore grades off gradually into ferruginous chert, an intermediate stage of alteration in the development of ore, and thence into an unaltered phase of the formation as cherty iron carbonate or amphibole magnetite rock. Sometimes the ore passes directly into amphibole magnetite rock at depth, due to the presence of intrusive material. Laterally the ore may grade out more or less gradually through ferruginous chert or ferruginous slate into the clean slate bounding that lens of iron formation, or may pass quickly from ore to slate. Layers of paint rock often interpose between the ore body and the enclosing slates. A very common relation is a layer of amphibole magnetite rock lying between the steeply dipping ore body and bounding slate on the footwall side, the amphibole magnetite rock thus forming the immediate footwall of that ore deposit.

Relations to Intrusives.

Drilling has shown bosses and dikes in connection with many of the Cuyuna ore bodies, intruded into the iron formation in a very irregular manner. Such intrusions affect the circulation of meteoric waters through that lens and so control in part the amount of the ore concentration.

If a dike cuts a lens of the iron formation, the waters circulating downward from the surface of that particular lens are prevented from reaching the portion of the lens lying below the dike. Hence concentration to ore, below the dike, will not occur as far as the directly downward circulating waters are concerned. This condition is illustrated by the ideal cross section on Fig. 9. If a lens, pitching gently along its strike is cut by a nearly vertical dike, the concentration on the upslope side is liable to be better than on the downslope side, due to the fact that the dike forms a barrier to the waters flowing along the pitch of the lens.

Where a dike or boss has penetrated a lens of iron formation

there has been developed in the lens, along the contact with the igneous mass, a zone of amphibole magnetite. Where such igneous masses have controlled the concentration to ore in a lens the circulating waters have not usually come in contact with the dike itself; but have been turned by the impervious zone of amphibole magnetite in contact with that dike. Therefore ore concentration is really limited by the zone of amphibole magnetite developed on each side of the dike and not by the actual intrusive; but since such zones are narrow and their relative position is that of the dike or boss which produced them, we may speak of the dikes or bosses limiting the concentration in a lens.

While the dikes have a direct effect on the ore concentration, the irregular masses or bosses have effects less easily marked. That these irregular masses, pushing up into the iron formation lenses, tend to pond or direct the flow in such lenses is obvious; but the actual effect which they will have can hardly be foreseen in each case, because of their irregularity of shape and position.

Pitch of the Ore Deposits and Probable Depth of Concentration.

The live question commercially on the Cuyuna today concerns the pitch of the ore deposits in general and the resultant probable depth of concentration.

On the Penokee-Gogebic range the characteristic occurrence of pitching troughs has been a great factor in the development of deep ore bodies. The iron formation is underlain by quartzites and overlain by slate. The whole series has been folded. Erosion has planed off the tops of the folds, so that the upturned truncated edge of the iron formation appears at the rock surface. The folded slate, iron and quartzite formation have been pierced at various angles by sheets or dikes or intrusive. Pitching troughs are formed by the intersections of these intrusive sheets with the steeply dipping impervious strata of slate or quartzite or with impervious layers within the iron formation itself. Portions of the iron formation are caught within these troughs, one limb of which is the dike and the other an impervious quartzite or slate. Circulating waters entering the formation on its upturned truncated edge flow downward along the bottoms of the troughs,

developing ore bodies on the limbs and along the bottoms. Occurring at frequent intervals along the upturned edge of the iorn formation and having a fairly uniform pitch to the west, along the strike, these troughs often underlie each other, so that a vertical hole drilled through an ore body at the surface is likely, if continued, to pierce an underlying ore body resting in another trough which reaches the surface at a point some distance away, on the strike of the formation. These trough deposits, pitching underneath each other, are characteristic of this range.

In turning to the problem of the characteristic occurrence on

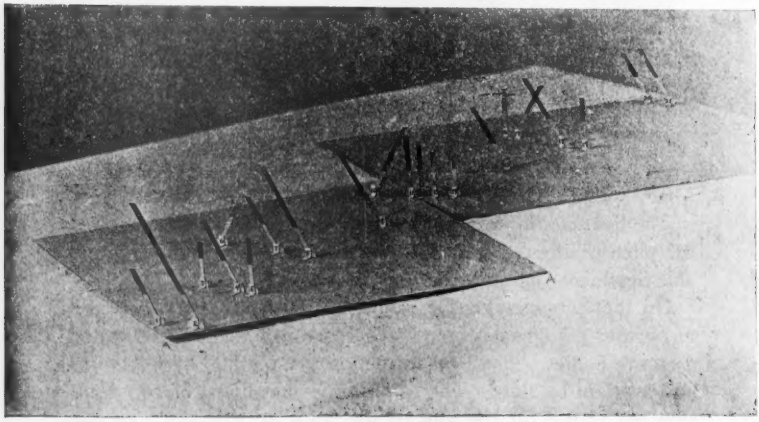


FIG. 10. Photograph A showing model, and drill holes in iron formation.

the Cuyuna Range the question arose as to whether the belt-like series of ore deposits or lenses is simply an overlapping and parallel series of canoe-shaped deposits, pinching towards surface at either end as they pinch laterally or whether deposits could be found showing continued and definite pitches along the strike of the formation and perhaps underlying each other.

Because of the impossibility of considering in their proper relations a mass of structural features as complex as those of

the Cuyuna by working from plane cross sections, the writer decided to take a number of the more thoroughly drilled areas throughout the range and build up in space the actual structure for each, as far as shown by the drilling. In order to make the results obtained easily understood a few words as to the method used would be advisable. Fig. 10 is a photograph of one of these models showing the structure for a certain locality as brought out by drilling. The vertical and horizontal scales of the model are the same. For purposes of convenience the model was photographed upside down, as the impression of space and distance comes out more clearly. The two rectangular plates supporting the columns represent the surface of the ground. The vertical and slanting columns represent the actual vertical and angle holes drilled into the earth at this point. The drilling represented by the model covers a little more than half a mile along the strike of the formation. From hole 1 to hole 20 one looks northeast along the strike of the lens. Line *AA* lies north and south. The light, uncolored portions of the columns near the surface of the plates represent the glacial drift. The black color represents iron formation partially or wholly altered to ore. The dark gray represents the slates bounding this lens of formation. The lighter gray represents unaltered iron formation. The two columns marked *I* represent intrusive.

The long lens of iron formation strikes north-northeast and dips steeply at angles varying from about 60° to 80° to the northwest. Hole 20 drilled against the dip of the formation soon passes out of the altered iron formation and into the slate bounding it on the footwall side. Hole 21, drilled to cut under hole 20, further down the dip of the formation, passes through the hanging wall slates, then through unaltered iron formation and into footwall slate. Coming southwest along the strike we find hole 16 in intrusive, hole 17 in footwall slate, and hole 19 in hanging wall slate, while 18 passes through hanging wall slate into the altered iron formation and then into the footwall slates. Hole 15 starting in ore passes into footwall slate. Holes 14 and 13 are in hanging wall slate, while hole 10 is in the slate on the

footwall side, which here contains narrow seams of altered iron formation. Holes 11 and 12 are in altered iron formation, hole 12 bottoming in footwall slate. Hole 9, starting in altered iron formation, passes at depth into unaltered iron formation. Hole 8 does the same. Hole 7 is in the slate on the footwall side. Hole 6 is in intrusive. Hole 5 is in hanging wall slate and holes 4 and 3 in altered iron formation. Hole 2, starting in the slate on the hanging wall side of the lens, passes into the altered iron formation and out again into the slate on the footwall side. Hole 1, starting in hanging wall slate, also passes through the formation and into footwall slate.

We have here an illustration of an ore deposit with a definite continuous pitch along the strike. The wholly or partially altered iron formation in any lens represents the path followed by meteoric waters flowing through that lens, while the unaltered iron formation and the slates bounding the lens on the hanging and footwall sides do not allow the water to pass through them and so limit and turn the flow. If then the contact between the altered iron formation on one hand, and the bounding slates and unaltered iron formation on the other can be traced throughout a lens, the altered iron formation will show where the water has percolated and the contact with the impervious slates and unaltered formation will give an impervious basin or trough which has limited and directed the flow of water and the resultant concentration to ore in the lens. In the lens illustrated by the model, the contact of the altered iron formation (ferruginous chert and ore) with the impervious slates and unaltered formation bounding it on sides and bottom has been clearly enough defined to show that these impervious bounding strata form a pitching trough. Commencing at the northeast end, it is plain that the slates of hole 20 and 21 mark the sides of the trough while the unaltered iron formation in hole 21 marks the bottom. Proceeding southwest on the strike the trough grows wider and that the altered iron formation is followed to increasing depths before the contact with the unaltered iron formation, marking the bottom of the trough, is reached. At the southwest end the lens

appears to be passing below the rock surface. This ore deposit has therefore been concentrated in a trough pitching to the southwest.

In this case it is reasonable to suppose that deeper drilling to the southwest of this property, on the strike of the formation, would disclose an ore deposit at depth. The circulating waters flowing along this southwestwardly pitching trough, having concentrated the iron formation to ore in the upper end of the trough, should have the same effect, to the southwest at a deeper level, on the iron formation in the lower end of the trough. The deposit is located in section 12, 43–32.

A number of other iron formation lenses or ore deposits were plotted and their structural relations studied in the manner here described. On the north range in sections 11 and 12, township 46–29 a large ore deposit, about a mile in length, quite narrow at its northeasterly end, was found to broaden out steadily on being followed southwest along the strike. The drilling here was not deep enough to determine, throughout the length of the lens, the contact between the ore deposit and the impervious strata underlying it. At the eastern end however, the impervious bottom layers were drilled into for a short distance along the strike. At this end ore body rests in an impervious trough, formed by the bounding slates and unaltered iron formation. The trough appears to have a southwesterly pitch, and the deposit as a whole opens out to the southwest. A similar set of conditions holds for a series of deposits on the south range in sec. 30–46–28, and in sec. 21–46–28.

Regarding the probable depth of ore concentration for the Cuyuna Range we have the following facts and inferences.

We know that on the Gogebic Range, where the ore is characteristically developed in pitching troughs, the ore deposits are found at depths up to 1,200 feet below the rock surface, an ore body near the surface often being underlain by a deeper deposit; which reaches the surface some distance away. Similarly on the Cuyuna ore deposits are developed in pitching troughs.

On the Gogebic range numerous intrusives pierce the folded

slates and iron formation. The relations of the intrusives to the slates and iron formation are such that pitching troughs have been characteristically developed throughout the iron formation. On the Cuyuna we also have numerous intrusives piercing the folded slates and included lenses of iron formation and the relations of the intrusives to the slates and iron formation lenses are similar to those of the Gogebic.

Therefore I believe that many of the Cuyuna ore deposits will be found to occur in pitching troughs and that exploration of the lower ends of these troughs by deeper drilling will reveal deep-lying ore bodies. The advisability of drilling beyond the lower limits of any particular ore deposit near the surface, depends on the careful study of the structural relations of adjacent iron formation lenses up and down the strike of the formation. If an adjacent deposit near the surface shows that it has been developed in a pitching trough and the pitch of that trough is in the direction of the deposit under exploration, then there is every likelihood that below the barren slates underlying this deposit will occur another deposit resting in the lower end of the trough in whose upper end is the adjacent surface deposit.

(*To be continued.*)

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

SPECIAL PROBLEMS AND THEIR STUDY IN ECONOMIC GEOLOGY.

DISCUSSION OF EDITORIAL BY J. D. IRVING.

Sir:—I have read the editorial on "Special Problems and their Study in Economic Geology," and agree with you that the time for specialization in subjects pertaining to economic geology appears to have arrived, and that the best equipped and strongest men or group of men in each subject should be given the opportunity of wide observation and for study and writing on special subjects.

I believe that in most states, and certainly in federal scientific and technical organizations, the authorities would willingly acquiesce in the expenditure of 25 per cent. or more of appropriation for special work, provided it is made clear that the purpose is the discovery of fundamental principles that will be of service in the development of science and natural resources.

In the earlier history of national and state surveys, many broad generalizations were drawn as the result of reconnaissance work extending over two or three decades, and a number of scientific reputations were won in this field. Later it was realized that more special and detailed work in selected areas must be done before another series of correlations and broad deductions could be ventured upon that would lead to the development of fundamental principles. This has been going on for the past twenty

years. In the course of such work there are usually a few men who, by their own initiative, begin special investigations, and all that is needed to obtain large results from them is encouragement and support by the administrative officials. In rare cases men of great originality and force will succeed despite neglect and antagonistic administrative influence. I am very glad that you called attention to the importance of working on special problems in economic geology, as it applies not only to that field but to many other fields of research.

CHARLES D. WALCOTT.

Sir:—I should be inclined to support your editorial on "Special Problems." The chief difficulty in the matter is the practical one of finding the right men for attacking the subject in the broad philosophic way and sparing them for this class of work. There is an immediate demand for the regional work and it keeps most staffs fully occupied trying to keep up with the districts that demand attention, but I think with you that the time is come when this work should be done. I have tried in a mild way to make a start on it here.

R. W. BROCK.

Sir:—In reply to your letter of November 12, relating to an editorial in No. 7 of ECONOMIC GEOLOGY, which I have for the first time had an opportunity of reading. I quite agree with the general statement of your editorial. In general my feeling is that the drawing of general conclusions cannot be successfully done until a large body of detailed descriptive facts have been obtained. I think that in the U. S. Survey, the last few years, a large amount of work has been done along the line of drawing such general conclusions, even though not much has been published. In connection with the work I had charge of there, it has been our policy for several years to push certain of the men into certain limited lines of work. For example, Mr. Munn has been pushed into the oil and gas work, and has been given every opportunity to study the oil and gas problem over as wide an area as possible, including from Pennsylvania to Alabama and westward

to Louisiana and Arkansas. He has prepared, if not published, some general conclusions, and has in mind many others, which we felt on the survey, were still open for discussion, and therefore, hardly ready for publication. In the same way Mr. Lines was given the clay work to specialize on. David White has already published some few generalizations on the subject of coal as well as Mr. Campbell, and many other subjects I know are being studied in that broad way by the men in charge of such work.

The reaching of such conclusions, however, is apt to be slow, and often its publication is long delayed as compared with the local descriptions, in which you reach a definite conclusion and pass on to the next piece of work, but there can be no question of the value of the study of all these facts to form the basis of generalization and laws, in fact I feel that the greatest value to be obtained in the study of geology is to be reached through these general studies.

GEO. H. ASHLEY.

Sir:—I am in hearty accord with your timely editorial and with the solution which you suggest.

Immediate and important economic results would follow the even partial solution of any one of the theoretical questions you enumerate.

It would be well if mature and experienced mining geologists, who have shown ability and originality in the handling of these general problems, could be able to devote the time and travel needful for the intensive and extensive study of any one of them. It is a field of work too wide for state geologists. It might well employ the best thought of the new Bureau of Mines, or perhaps better, engage the attention of some public-spirited mine owner, who could thus let a portion of the profit of a great mine promote the larger interest of mining in general.

B. K. EMERSON.

Sir:—The article of the editor on "Special Problems and their Study in Economic Geology" brings up some of the matters that rise occasionally before every gray-haired geologist whose time is fully occupied with the problems immediately in hand.

The article referred to lays especial stress on the fact that the great bulk of our geological reports contain vast quantities of information that is useful to various classes of people, but that the man who wants information on some special problems has to wade through and sift a vast amount of information in order to get very little of the particular kind of information he is looking for.

This characteristic of publications on geology is not confined to publications on geology by any manner of means.

Every man who undertakes to solve any kind of a problem is in the position of a hunter who follows his game through a forest where at almost every step his attention is attracted, or is liable to be attracted, by other game that starts up on the right and on the left to tempt him away from the chief object of his pursuit.

Who has not seen the inexperienced dog lured from the track of nobler game by a jack rabbit starting up close under his nose?

A geologist must know what he wants and go after it; and he must not allow himself to be inveigled from the chief object of his study by every collateral problem that he runs across, however large, important and attractive it may be.

In my opinion the chief difficulty referred to by Dr. Irving is inherent and inevitable.

I never collected data on a given piece of geology, that, upon writing up my notes, I did not want to go back and examine things all over again. This used to trouble me greatly when I first began. One day I asked a fellow geologist if he ever wanted to go back and look at things again. He replied that he never wanted to do anything else. From that day to this I have found conscientious geologists the world over wanting to "just have another look at it." And why so? And what has "another look at it" to do with the question in hand? Does it not mean simply that we never get out of any problem all that there is in it? And is this not inherent in every scientific problem? I think so.

The main thing is for one to decide what problem he is going

to attack, and then to attack it, and stay with it. Any other course seems to be impracticticable and unsatisfactory. It is not uncommon for investigators to become so buried beneath the accumulations of their own data that they can't move—can't use any of it. Surely such a mistake is as fatal to progress as any other mistake.

I am disposed to think that the difficulty about getting information on the subjects mentioned by Dr. Irving comes from the simple fact that no one has gone into the field to work on those particular problems. The data available in the solution of them are available by mere accident.

The reference to the universities is very much to the point. Our federal and state surveys necessarily have their limitations; the universities on the other hand have no limitations save those imposed by the lack of funds. If the head professor wants a piece of advanced work done in a particular way he has only to indicate the way. To be sure if he requires the candidates to study a problem under all sorts of climatic, topographic, and geologic conditions, all the way from the equator to the poles, he is liable to encounter the problem of funds with which to have the work done, but otherwise he has a free hand.

And if new methods of research are to be devised to whom is the world to look for such methods if not to the universities? Is it not the function of the universities to improve old methods and to devise new ones and keep them all at the highest possible degree of efficiency?

J. C. BRANNER.

Sir: I may be called pessimistic, but my ten years' experience with state geological survey work has given me a somewhat different point of view from those who have been engaged almost exclusively in educational work and privately endowed scientific investigations.

I believe that nearly everyone in charge of state geological survey work feels very keenly the limitations placed upon his investigation of broad scientific problems, on account of the

public demand for that which may be useful in the immediate development of the mining industry of the state. The public or such part of it as I have come in contact with, demand descriptive geological literature, and not theoretical considerations of the broad problems of the origin of the ore deposits. Such work as is conducted along this line must of necessity be incidental to that which is conducted to meet the public demand.

The problems suggested in your editorial, pages 275–276, are such, that should they be taken up seriously by the state geological surveys, with which I have been connected, it could only be through the use of time which the legislature had otherwise appropriated for. It was inferred that the politician should be made to understand that the scientific man is the one to define how the appropriations for geological work should be expended. Did you ever try to educate any of the law-makers of the "sovereign" states along this line? Do you mean to infer that there has been no effort to educate our constantly changing legislative personnel as to the true needs of the geological surveys? What do you suppose would be the result if you should ask one of the legislatures of the middle west states for an appropriation to study "The effect of climatic conditions on the superficial alteration of ore-deposits"?

The reports, which you refer to on page 672 as, "These are the state reports which, etc., . . . may be serviceable to a few farmers and may help to enhance the popularity of local politicians" may have been the result of good judgment and I doubt if one can question the wisdom of the policy which prompted their issuance without knowing the local conditions surrounding the maintenance of the Geological Survey in the state from which these reports emanated.

True, such reports may have very little scientific value, but the director of the survey may have acted wisely. The appropriation for that biennial period may have been in part wasted, but that waste may have served to perpetuate the geological survey for many years.

Again, one must not lose sight of the fact that the state geolog-

ical surveys are close to the people and that "farmers" must be treated with the same consideration that is given mine owners. It is my honest conviction that it is the first duty of the state geological surveys to do those things which express the will of the people whom they represent. If this were a country ruled by minorities, and not by majorities, it might be different; but we live and operate under a democracy, and I do not believe in abrogating the rule of the majority.

Further, it appears unwise to publish anything which may discredit the state geological surveys as a whole. They have enough to burden their souls with already.

Again some of the state surveys are not permitted to pay the expenses incurred by traveling outside of the state, from the appropriations, which effectually prevents investigations broader than their own commonwealth.

These are a few of the difficulties that occur to me in carrying out your suggestions. They, of course, do not touch in any way, the desirability of your proposition from a theoretical standpoint or from the standpoint of the United States Geological Survey. It expresses only my own impressions as a result of state geological survey experience.

E. R. Buckley.

Sir: Your editorial is very timely. Why not as an entering wedge suggest the publication of a uniform system of cross references for the Geological Survey publications, using as a basis the seven special problems as per your editorial.

Geologists and mining engineers will doubtless all agree in admitting "the fault," as pointed out in your editorial, *i. e.*: the lack of proper study of "special problems" by our federal and state surveys. There can be no discussion on this point.

There remains therefore only the question of ways and means of remedying the fault.

My suggestion, *i. e.* to have published a system of cross references for the Geological Survey (Federal) publications, using as a basis the seven special problems as per your editorial, was

made with the intent that it should be followed by publication in separate volumes of those papers or extracts from reports dealing with a particular subject.

Should the government comply with the above suggestions, there would then be available in concrete form a series of observations which would show what had been done to date, and which would be of very great value to geologists and engineers. This with no reorganization of departments, no large appropriations, and in the minimum of time.

At a later date the question of employing specialists to study the various problems could be taken up much more intelligently and more economically.

RUSSELL T. CORNELL.

REVIEWS

Lehre von den Erzlagerstätten. Von DR. RICHARD BECK (Freiberg). Dritte, stark umgearbeitete Auflage in zwei Bänden. Berlin, Gebrüder Borntträger, 1909.

The third edition of Professor Beck's well-known book on ore deposits appears in greatly changed form. The single volume of about 700 pages is replaced by two volumes aggregating 1,100 pages. Not only has the material been expanded, but the arrangement and classification are notably different, and in most cases greatly improved. The latest literature is incorporated and a noteworthy phase of this consists in summaries of the difficulty accessible Russian description of ore deposits. Another commendable feature is the wealth of new material from the author's own observations or from notes of his students now scattered in all parts of the world. While all this has greatly augmented the scientific value and the completeness of the book, it has hardly increased its value as a textbook for the student, who is still feeling the need of a compact compendium of the science of ore deposits. The defects that can be charged against this work are mainly those inherent in the plan adopted—that is a practically complete description of all known important occurrences of metallic ores. On account of this some of the general chapters of summary and discussion are neglected or unduly shortened. Sooner or later we shall be forced into another path, for, like petrography some ten years ago, the science of mineral deposits is gradually emerging from a maze of description into a more systematic treatment. No one can fail to be impressed with the enormous burden of work involved in the writing of a book like the one under review, and surely no one could have performed the work better than Professor Beck. The critical treatment of the overwhelming literature leaves as a rule little to be desired, and the exactness in foreign names is remarkable. In short, the book can be cordially recommended for those desiring a work of reference on the ore deposits of the world. A running criticism of the various chapters follows; it must be said that in view of so much general merit it seems almost invidious to find fault with some details.

In the new classification the former fundamental division into epigenetic and syngenetic deposits has been abandoned as well as the untenable class of "deposits other than veins." Instead, the following

improved arrangement has been adopted:

1. Magmatic segregations.
2. Contact metamorphic deposits.
3. Veins
4. Bedded veins } Morphologic facies of a single genetic group.
5. Stocks
6. Gossans and secondary enrichments.
7. Sedimentary deposits.
8. Detrital deposits.

Even this new scheme is of course open to some objections, chiefly in that certain genetically different things are brought into juxtaposition. Thus, "stocks" of earthy manganese ores assuredly formed near the surface are placed next to the copper deposits of Bisbee of decidedly deep-seated origin.

No one needs to be told that Professor Beck is an ardent supporter of the theory of the derivation of many classes of ore deposits from magmatic sources; this view finds frequent expression in the book. The magmatic segregations are treated in 80 pages, alone twice the space allotted in the older edition. The review of processes of differentiation is hardly adequate, Soret's principle, for instance, being quoted as one of the principal factors. Iron ores, titanic iron ores and pegmatites are excellently treated. The sulphide magmatic segregations are also given much space, but throughout this part runs a clearly discernible doubt as to the importance of that process. The author is much more inclined to ascribe such alleged deposits to "after effects" of intrusion by somewhat later ascending solutions. The Sudbury deposits are described with an indicated preference for the latter mode of origin. He also points out that in many cases the sulphides have been formed by subsequent dynamo-metamorphic processes. Undoubtedly most of these deposits show evidence of pressure, but it seems to the reviewer that the author has underestimated the capacity of a magma to dissolve sulphides. With little reason the Rossland deposits are included in this chapter; likewise, the Monte Catini copper deposits would seem out of place here. The important occurrence of zeolites at the latter place is overlooked.

The contact metamorphic deposits have justly been assigned an independent place, and a short discussion precedes the detailed description; the theory of acquisition of material from the magma is strongly upheld. Unfortunately the description begins with a number of more or less obscure occurrences, so that it becomes most difficult for the student to obtain a clear and convincing picture of the interesting division. Its great importance and wide distribution in the southwest of the United States and in Mexico is scarcely appreciated as yet.

The veins are described very fully on 270 pages, and this part is pre-

ceded by 100 pages on vein deposits in general, origin of fissures, etc. The divisions adopted are called "formations" and follow the older German usage; for instance, cassiterite formation, copper ore formation, silver-lead ore formation, gold ore formation, etc., a usage which places undue weight on the particular metallic contents of the vein. The description of the cassiterite vein is much extended and improved. The copper veins follow, beginning with those containing tourmaline. In the silver-lead formation, the typical veins of the Wood River region in Idaho might well have found mention. The division of the veins with rich silver ores has been greatly expanded by the addition of valuable descriptions from Mexico. The deposits at Arqueros in Chile are referred to, but not the occurrence of zeolites at that place.

Important additions have been made to the chapter on the gold-bearing veins. Their connection with pegmatites is strongly insisted upon; an inclination is shown to ascribe certain classes of veins to certain divisions of geologic time, for instance, in the scarcely warranted statement that the gold quartz veins range in age from the Paleozoic to the older Tertiary.

The rare occurrence of veins carrying selenides are comprised under a separate paragraph which contains much new and valuable information from the interesting deposits of Sumatra. In this connection the selenides of Skrikerum find mention; this locality is, however, in southern Sweden, not in Norway. Another instance of the juxtaposition of genetically wholly different things appears where the hydrosilicate nickel ores are described immediately after the cobalt ores of Schneeberg in Saxony.

Much valuable and new information is given under the heading of quicksilver ores, especially from Almaden. The generally younger age of the cinnabar veins might have been emphasized as well as their dependence upon igneous rocks, as well brought out for the Mediterranean region by De Launay's recent paper: "La métallogénie de l'Italie."

The second volume begins with a long chapter on the distribution of the ore in the veins, as well as on the influence of the vein-forming solutions on the country rock; the latter subject is scarcely treated as fully as the subject requires. The analyses, for instance, which are given to represent the process of propylitization are very unsatisfactory. A chapter on the geological age of the veins might well have been added. On the other hand, this is followed by a rather long and very excellent discussion of the theories of origin of the veins. The presence of metals in thermal waters is mentioned, but hardly sufficiently critically, and this is followed by a review of modes of origin of thermal waters as well as the conditions of precipitation. Needless to say that much of the chapter applies to deposits other than veins.

Now follow chapters on the bedded veins and beginning again by a great number of descriptions of doubtful and enigmatic occurrences such as Ammeberg, Bodenmais and Broken Hill. Bergeat's interpretation of the pyrite deposit of Bodenmais as a product of intrusion is not accepted by Beck. Among other examples included here are the pyritic deposits of Röros, Rio Tinto, Agordo and Rammelsberg, and the gold-bearing conglomerates of the Witwatersrand. Professor Beck is of the decided opinion that the latter are of epigenetic origin.

The epigenetic stocks or irregular deposits come next, and they certainly form a variegated assortment. Residual manganese deposits, Laurion, Bisbee, Moresnet, Silesia, Leadville, Lake Valley, Sierra Mojada and the Homestake—all these occurrences are epigenetic stocks. One is reminded of Van Groddeck's remark that he never could understand why some people derive such satisfaction from the information that a certain occurrence is a "stock."

The description of the zinc-lead deposits of the vicinity of Aix-la-Chapelle and in Silesia are good, but some additional data as to the relation of waterlevel and oxidation of zinc to calamine would have been desirable. One also misses a scale to several sections which would give a key to the depth of the deposits. Professor Irving's report on the Northern Black Hills (Prof. Pap. 26, U. S. G. S.) is apparently one of the few publications which have escaped the author's notice.

An interesting chapter is devoted to the chemistry of the gossan and to oxidized ores in general. Following this, comes an altogether too short chapter on secondary sulphide enrichment, mostly consisting of doubtful chemical equations. The purely sedimentary ores are disposed of in comparatively brief space. Here we find the Scandinavian iron ores, including even the Kiruna deposit together with epigenetic stocks and more decidedly sedimentary ores like the hematites of Striberg. The author recognizes of course that various things are here included, but desired to treat this class of occurrence at one place.

The more recent, clearly sedimentary ores of the Paleozoic and post-Paleozoic column follow as well as an excellent chapter on detrital deposits.

Any one inclined to find fault would say that for an ideal text-book there is too much detail and too few generalizations. But he would be unjust indeed who would fail to see the incalculable value to the science of this exact and conscientious assemblage of the basal facts. It is unquestionably a book of the highest merit.

W. LINDGREN.

History of the Gems Found in North Carolina. By GEO. F. KUNZ. Bull. No. 12. North Carolina Geol. and Economic Survey. Raleigh, 1907. Pp. xvii + 58. Plates XV.

Gems and Precious Stones of Mexico. By GEO. F. KUNZ. Mexico, 1907. Pp. 54.

These two volumes contain summaries of the existing knowledge of the nature and occurrence of the gem material found in the areas indicated by their titles.

North Carolina is the leading state in the union with respect to the varieties of gem material found within its borders. All of these were discovered incidentally in the course of mining for gold, corundum, mica or monazite. In the first volume Mr. Kunz gives an historical sketch of gem mining in the state, and brief discussions of all the minerals that have been utilized as gems. The book is illustrated by handsome plates showing some of the gems in their natural colors.

In the second volume the method of occurrence of all the known gemstones of Mexico are briefly outlined. The only gem systematically exploited at present is opal and the only important ornamental stone is Mexican onyx. In addition, the pink garnet, rosalite, is worked to some extent in Morelos and pyrope is gathered from the weathered rocks in Chihuahua. Probably the most significant pages in the volume are those dealing with the occurrence of jade. As is well known, this substance was regarded with great favor by the ancient Mexicans. The material is known to occur as river pebbles and most of the material found in Mexican ruins is supposed to have been obtained from them. Since the distribution of the jade pebbles is circumscribed within comparatively narrow limits it is thought they must have originated within these limits. Its source, however, has not yet been discovered. Diamonds, ruby, sapphire and emerald have been reported from several localities but authoritative information about them is lacking. Topaz is abundant in both rhyolite and trachite at a number of points, some of the crystals measuring three inches in length. They have, however, not been obtained in commercial quantities.

Both books are authoritative in their spheres. Each is comprehensive.

W. S. BAYLEY.

Tables for the Determination of Common Rocks. By OLIVER BOWLES. New York, D. VanNostrand, 1910. Pp. vii + 64. Price 50c.

This little book of 64 pages is an attempt to furnish a concise scheme for the determination of rocks in the field, using only their macroscopic characteristics for the purpose. The tables are prefixed by a few notes on rock classification and a key for the ratio determination of rock-forming minerals.

The arrangement of the rocks in the tables is entirely arbitrary. Seven groups are recognized, viz., glassy, ashy or cellular, granular crystalline, porphyritic, dense, banded, and fragmental. Following the table is a short chapter on the employment of rocks as building stones and a glossary containing brief definitions of lithologic terms.

While most of the rocks commonly met with are listed in the book there are a few—the monzonites, for instance—that are not referred to in any way. Further, the distinctions made between some of the commonest types are not clear enough to be of determinative value. None of the rocks is defined, so that the tables will be of value principally to those who are already familiar with the usually recognized rock-types.

W. S. BAYLEY.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN AND J. A. ALLEN.

METALLIFEROUS DEPOSITS.

COPPER.

Copper Mining in Metcalf District, Arizona. By P. B. SCOTLAND. Eng. & Min. Jl. Vol. 90, No. 3, pp. 118–123.

Deals largely with mining and milling methods. The country rock is granite or granite porphyry and the ore deposits are classified as (1) contact deposits between porphyry and limestone quartzite or granite; (2) "lode deposits" in or close to fault fissures in porphyry; (3) lode deposits in fault fissures in granite. The sulphide ore is chalcocite; the oxide ore is azurite, malachite, cuprite, and chrysocolla; and are derived from the sulphide ore. The ore is of low grade. A.

The Kosaka Copper Mine of Japan. Min. & Sci. Press. Vol. 101, No. 16, pp. 503.

The oxidized zone was originally worked as a silver mine, now the sulphides are mined. The ore contains copper principally and some zinc. The minerals present are pyrite, calcopyrite, galena, blende, barite and sometimes quartz. The ores occur as an impregnation in sandstone, in close contact with a dike of liparite (a felsitic purplish rhyolite). A.

Ore Deposits of Cananea Mining District, Mexico. By S. F. EMMONS. Eng. & Min. Jl. Vol. 90, No. 9, p. 402.

The ore bodies are grouped under three types: (1) Contact metamorphic deposits in a band of limestone between granodiorite and diorite-porphyry. The limestone is marmorized, silicified, and garnetized; chalcopyrite is the ore mineral and is associated with the garnet, in all deposits under this type. (2) Hydrothermal deposits

are the most important. Limestone and quartzite are cut by granite-porphyry and diorite-porphyry; it is with the diorite that the ore occurs. (3) Igneous-contact deposits occurring near the contact of quartz porphyry and diorite-porphyry and in either rocks. The ore occurs as a replacement, vein, or impregnation of the country rock. A.

Economics of Secondary Enrichment—II Copper. By A. M. FINLAYSON. Min. & Sci. Press. Vol. 101, No. 4, p. 111.

Cites the importance of the careful study of secondary enrichment of copper ores, giving many examples. The alteration zones of copper deposits are well established. A surface leached and impoverished zone of gossan; oxidized ore zone; enriched sulphides; and finally zone of unaltered and "lean" sulphides. Many examples are given where the order holds. The determining factors of secondary enrichment are (1) the metal or ore (certain ores are most affected); (2) the gangue (sulphide enrichment not prevalent, if oxidized ore is in a carbonate gangue); (3) country rock (its physical and chemical character are important); (4) the fissures (where they have been formed after the deposition of the ore); (5) the climate (which involves temperature and rainfall, much still remaining to be found out as to the extent of secondary enrichment in zones near the equator); (6) topography (which influences ground-water level and hence the degree of alteration); (7) the geological age and history of the deposit (important in that the older rocks are less susceptible to alteration when exposed on surface). Considering ore deposits collectively all factors are of great importance. A.

CHROMIUM.

Some Chromite Deposits in Western and Central California. By E. C. HARDER. U. S. G. S. Bull. 340–D, 1910, pp. 19–35.

Describes the different deposits, reviews opinions as to origin in general, and discusses origin of the California deposits, recognizing (1) deposits of hard black ore grading into serpentine, (2) deposits of hard black ore having sharp contacts with the serpentine and (3) deposits of soft gray ore in decomposed serpentine. (1) and (2) are results of magmatic differentiation, during, or before, final consolidation of the magma. L.

GOLD AND SILVER.

Samsonite, ein manganhaltiges Silbermineral von St. Andreasberg im Herz. By WERNER and FRAATZ. Centralb. f. Min. Geol. u. Pal. June 1, 1910, pp. 331–336.

Describes the occurrence and gives chemical analysis of a new species with the formula $2Ag_2S.MnS.Sb_2S_3$.

The Solution of Gold in the Surface Alteration of Ore Bodies. By A. D. BROKAW. Jour. Geol. Vol. XVIII., No. 4, 1910, pp. 321–326.

Gives results of experiments showing that (1) in dilute natural solutions ferric salts have but slight effect; (2) manganese dioxide is efficient only in the presence of chlorides; (3) mixtures of ferric sulphate, sulphuric acid, and sodium chloride in concentrations common to mine waters readily dissolve gold in presence of MnO_2; free hydrochloric acid is much more affected than same amount of Cl in ferric chloride; ferrous salts do not prevent solubility of gold in presence of MnO_2; solution of gold is practically limited to the oxidized zone. L.

The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold-Deposits in the United States. By W. H. EMMONS. Amer. Inst. Min. Eng. Bull. 46, 1910, pp. 767–837.

Cites and discusses natural and experimental evidence to show that the presence of manganese in the gangue is necessary for the solution and downward concentration of gold. $Fe \cdot SO_4$ is the chief precipitating agent. The subject is discussed under the following headings: I., Introduction and Summary; II., Salts contained in the waters of gold and silver mines in non-calcareous rocks; III., Chemical experiments in the solution and deposition of gold; IV., Discussion of experiments; V., The transfer of gold in cold solutions; VI., Review of mining districts. L.

Geology and Ore Deposits of Hedley Mining District, British Columbia. By C. CAMSELL. Geol. Surv. Canada, Memoirs. No. 2, No. 1093, 218 pages, 20 plates, 8 figs., 4 maps, 1910.

Gives the results of a thorough detailed study of this important (economically), interesting and unique mining district. The sediments are principally limestone and quartzites which are placed in the Cache Creek group (Carboniferous). These are cut by stocks, dikes and sheets of diorite and gabbro. Economically the district is very important in the unique character of the ore deposits as found in the Nickel Plate Mine, which in 1908 produced $2,250,000 worth of gold. This ore deposit is becoming world-known. It is unique in that it is a contact metamorphic deposit in which the gold is intimately associated with arsenopyrite, either in invisible particles or in solid solution with the arsenopyrite.

The ore bodies are irregular in outline, with frequently a well-defined footwall along an intrusive gabbro sheet. The country rocks are an impure altered limestone, in which the carbonates have been replaced by silicates, and intrusive gabbro. The ores contain arsenopyrite, pyrrhotite, pyrite, chalcopyrite and sphalerite. The arsenopyrite carries the gold, and the primary ores are of contact-metamorphic origin, formed contemporaneously with the gabbro intrusion. Free gold has been found at the surface. The zone of oxidation is shallow. Secondary enrichment is also evident in places.

The writer concludes that regarding the genesis of the ore—"contact metamorphism by the intrusion of igneous rocks into limestones during which the primary ores were formed, followed by secondary enrichment by descending meteoric waters will satisfactorily explain every occurrence of workable ore in the district." A.

Geology of Hostotipaquillo Ore Deposits, Mexico. By S. J. LEWIS. Min. & Sci. Press. Vol. 101, No. 11, p. 335.

The country rocks are andesite, basalt, and flows of rhyolite. The ore consists of quartz cementing the brecciated rhyolite, the country rock impregnated with gold- and silver-bearing sulphides. The country rock is cut by a later dacite, which fractured the surrounding rock and was itself fractured. Mineral solutions formed veins which are low in metals in the dacite but rich in gold and silver in the andesite. The writer states that the determining factor for this phenomenon is the difference in alkalinity in the two rocks. Secondary enrichment has formed bonanzas along local faults. A.

Preliminary Notes on Geology of Porcupine District of Canada. By A. A. HASSAN. Can. Min. Jl. Vol. 31, No. 18, p. 561.

A very brief note in which the writer states that the gold occurs in veins and "dikes" of quartz which cut a Keewatin and Precambrian complex. The gold is usually found within large masses of green chloritic schist. A.

The Altar Gold Placer Fields of Sonora, Mexico. Eng. & Min. Jl. Vol. 90, No. 14, p. 651.

Gold was first found in this district in 1799, but the ground is now becoming thoroughly worked over. The gold is embedded in a black sand in the "argamasa," which is a conglomerate containing mica, hematite, black sand, quartz and fragments of the country rock cemented with calcite. This conglomerate is crushed and the gold and black sand washed out. This material is hand-panned. Very rich pockets have recently been found at the foot of waterfalls in the channels of old water courses which are now filled with argamasa. A.

Bedded Gold Quartz Veins near Poto, Peru. By E. THURSTON. Eng. & Min. Jl. Vol. 90, No. B, p. 597.

Briefly notes the presence of thin bedded, gold-bearing quartz veins in supposed lower Silurian slates. These veins are locally known as "mantoa." The ore contains argentiferous gold, pyrite, stibnite, galena, sphalerite and some copper.

The Weaverville-Trinity Center Gold Gravels, Trinity County, California. By D. F. MACDONALD. U. S. G. S. Bull. 340–A, 1910, pp. 40–50.

Gives location and physiography, and describes the different placers. The deposits are large, of low grade, and some are workable by hydraulic methods, especially along Trinity River. L.

Gold Mining in the Randsburg Quadrangle, California. By F. L. HESS. U. S. G. S. Bull. 340–A, 1910, pp. 15–39.

Gives general description of the quadrangle, topography, geology, history and present conditions of mining, distribution and occurrence of the gold deposits. Three types of deposits are described: fault-lode, stockwork and fissure-vein. They are genetically connected with intrusions of granite and granite-porphyry.

Notes on the Placer Deposits of Greaterville, Arizona. By J. M. HILL. U. S. G. S. Bull. 340–A, 1910, pp. 3–14.

Gives location, production, geology, distribution of gold-bearing deposits, character of gravels and bed rock, character and origin of the gold (erosion of sulphide veins in neighboring mountain), methods of working. As to the future of the camp, values are still there, but their lack of water concentration on bed rock together with the scarcity of water will retard, or prohibit, future development. L.

Placer Gravels of the Sumpter and Granite Districts, Eastern Oregon. By J. T. PARDEE.

The placer gravels include (1) older high-terrace gravels capped by volcanic material, and (2) more recent gulch or valley gravels along the sides of present streams, rich in unglaciated territory, but lean or barren in glaciated districts. The extent of remaining gravels and future production are considered. L.

IRON.

Some Iron Ores of Western and Central California. By E. C. HARDER. U. S. G. S. Bull. 430–E, 1910, pp. 3–11.

Describes the Perfumo Canyon deposit in San Luis Obispo Co. (a nearly vertical bed of limonite in the Franciscan formation), and

iron ores of Calaveras Co. (small deposits of brown ore replacing schist or slate), and the Holaling deposit in Placer Co. (contact metamorphic deposits in quartzite at contact with diabase). L.

Preliminary Report on Pre-Cambrian Geology and Iron Ores of Llano County, Texas. By S. PAGE. U. S. G. S. Bull. 340–E, 1910, pp. 40–52.

Gives geology, general and locality descriptions of the ores. The origin (thought due to contact metamorphism) will be discussed in a later report. Present geologic indications are not very promising, but more workable bodies may be discovered by further prospecting. L.

Deposits of Brown Iron Ore near Dillsburg, York Co., Pennsylvania. By E. C. HARDER. U. S. G. S. Bull. 340–E, 1910, pp. 34–39.

Gives location and history, geology, describes ore deposits (irregular masses in clay) and mining methods and discusses origin of the ores (downward concentration, with deposition either along impervious beds or along lines of faulting). L.

The Jauss Iron Mine, Dillsburg, Pennsylvania. By A. C. SPENCER. U. S. G. S. Bull. 340–E, 1910, pp. 31–33.

Corrects certain statements made in Bull. 359, as result of evidence exposed in the unwatering of the mine. The position and origin of the ore (replacement of limestone conglomerate beds, but not of intervening shale beds, by magnetite at contact with diabase) and advice as to development are given. L.

Iron Ores near Dayton, Nevada. By E. C. HARDER. U. S. G. S. Bull. 430–E, 1910, pp. 24–30.

Commercially important deposit northeast of Dayton are contact deposits between soda granite and limestone. The surface ore is high grade; in depth it is strongly impregnated with calcite, and in some places selenite. One paragraph is given to deposits southwest of Dayton (veins of hematite and magnetite in andesite). L.

The Iron Age Iron Ore Deposit, near Dale, San Bernardino County, California. By E. C. HARDER and J. L. RICH. U. S. G. S. Bull. 430–E, 1910, pp. 12–23.

Describes location and geology, description of intrusive rocks, metamorphism and weathering, extent and structure of the iron deposits (veins of hematite and magnetite in granite and granite porphyry) origin of the ore (deep-seated solutions, as indicated by association in the veins of hematite, magnetite, epidote, and garnet. L.

Bathurst District, New Brunswick. By G. A. YOUNG. Can. Min. Jl. Vol. 31, No. 16, pp. 488–492. (Abstract from Summary Report, G. S. C., 1909.)

Minerals of economic importance are iron and manganese, principally the former. The Nipisiguit iron deposits are found as "flattened lenses" within a quartz porphyry of post Ordovician age. The ore is largely magnetite with some hematite. The writer places these iron deposits in the pegmatitic group type; their formation being in some way aided by the action of intrusives, but not directly connected in origin with the quartz porphyry. A.

Iron Occurrence in the Eastern Half of the United States. Eng. & Min. Jl. Vol. 90, No. 5, p. 206.

A complete, compact, tabulated list according to states, districts, and variety of ore, of all the active iron mines during 1908, in eastern portion of the United States. A.

LEAD AND ZINC.

Problems of Ore-Deposition in the Lead and Zinc Veins of Great Britain. By A. M. FINLAYSON. Quart. Jour. Geol. Soc. (London). Vol. LXVI., No. 262, 1910, pp. 299–238.

Considers the source of the ores, the vein solutions, metasomatic processes, paragenesis, influence of country rock on ore-deposition, and secondary alteration. Juvenile waters deposited the ores (chiefly sulphides) causing sericitization and carbonatization of siliceous rocks, and silicification and dolomitization of limestones. Deposition was chiefly in open spaces, and persisted over a vertical range of 5,000 feet. Secondary alteration has caused enrichment of silver, depletion of blende, and the development of metasomatic calamine. L.

Orzark Lead- and Zinc-Deposits; Their Genesis, Localization, and Migration. A. I. M. E. Bull. 43, 1910.

An interesting reply by C. R. Keyes to criticisms of E. R. Buckley, with incidental praise to the reports of Arthur Winslow. L.

Notes on the Mineral Deposits of the Bearpaw Mountains, Montana. By L. J. PEPPERBERG. U. S. G. S. Bull. 340–C, 1910, pp. 3–14.

Gives results of reconnaissance study, including outlines of the history of development, geology, mode of occurrence of the ore deposits, and brief descriptions of mines and claims. Mineralization is widely diffused, and in only a few places has there been sufficient concentration to form ore-bodies. The veins are "the roots of former more extensive deposits." L.

MOLYBDENITE.

Some Occurrences of Molybdenite in the Santa Rita and Patagonia Mountains, Arizona. By F. C. SCHRADER and J. M. HILL. U. S. G. S. Bull. 430–D, 1910, pp. 6–15.

Describes the several mines and prospects. The molybdenite occurs either impregnating granite or in quartz veins cutting granite. The future value of the deposits depends on further development. L.

MERCURY.

Notes on the Occurrence of Cinnabar in Central Western Arizona. By H. BANCROFT. U. S. G. S. Bull. 430–D, 1909, pp. 3–5.

A brief description, outlining topography and geology, and occurrence of the ore. The cinnabar was probably derived from mercurial tetrahedrite. L.

PLATINUM.

Platinum in Southeastern Nevada. By H. BANCROFT. U. S. G. S. Bull. 340–D, 1910, pp. 44–51.

Gives general description of the region, geology, petrography and chemical analysis of peridotite dikes, developments and production. The one carload shipped gave 0.13 to 0.15 per cent. platinum. Distance from railroads is the chief drawback. L.

TITANIUM.

The Virginia Rutile Deposits. By T. L. WATSON and S. TABER. U. S. G. S. Bull. 340–D, 1910, pp. 52–65.

Describes topography and general geology, the chemical composition of the rocks, the varieties of rutile ore, the history of mining development, and the uses of titanium. The rutile occurs as grains more or less abundantly disseminated in (*a*) pegmatite and (*b*) the ultrabasic rock, nelsonite. The Virginia deposits, since 1902, have supplied all the domestic and some of the foreign markets. L.

TUNGSTEN.

Notes on Tungsten Deposits near Deer Park, Washington. By H. BANCROFT. U. S. G. S. Bull. 340–D, 1910, pp. 66–68.

Gives location and description of the deposits. The tungsten mineral is hubnerite in lenticular quartz veins. Pyrite and argentiferous cosalite (sulphide of lead and bismuth) may also be present, the latter in possible commercial quantity. L.

Notes on the Occurrence of Tungsten Minerals near Calabasas, Arizona. By J. M. HILL. U. S. G. S. Bull. 340–D, pp. 16–18.

Describes wolframite-quartz veins associated with lamprophyr dikes in granodiorite. The wolframite is too widely scattered to pay for the mining. L.

Tungsten Deposit of Moose River, Nova Scotia. By E. R. FARIBAULT in Summary Report Geol. Surv. Canada, 1909, pp. 228.

The scheelite-bearing veins are classed as "interbedded veins," as they coincide with bedding planes. They are distributed on either side of the axis of an anticline which gives rise to gold bearing saddle veins. The veins vary from a few inches to two feet in width. The veins contain quartz, scheelite and mispickel, with some white mica and tourmaline. The scheelite on the selvage of the veins is decomposed to tungstite. The writer concludes that "the character of the veins, their constituents, the presence in them of mica and tourmaline, and the metamorphism of the country rock adjoining the veins, all tend to prove that the tungsten deposits are the result of deep-seated emanations, along a zone of fractures following the axial plane of the Great Moose River anticline, at the close of the period of granite intrusion." (Abstracted in Can. Min. Jl., Vol. 31, No. 18, p. 549.) A.

NON-METALLIC DEPOSITS.

ASBESTOS.

On the Distribution of Asbestos Deposits in the Eastern Townships of Quebec. By J. A. DRESSER. Can. Min. Jl. Vol. 31, No. 15, pp. 465–470.

The asbestos occurs in a "serpentine belt" which cuts Cambrian and Ordovician sediments. Three guiding features assist in the location of asbestos deposits: (1) Purity of the serpentine, which depends on the purity of the parent rock (peridotite) and on the degree of serpentinization. (2) Fracturing, asbestos forming in the fractures and through expansion causing other fractures, so that fracturing may be regarded both as a "cause and an effect of serpentinization." The width of the asbestos vein is proportional to width of serpentine band, and is as a rule about one third of the width of the band of serpentine. (3) Presence of granites, asbestos frequently being found about the granite intrusives. The intrusion has been followed by fracturing and the presence of magmatic waters in the intrusive has probably assisted largely in the serpentinization. A.

CLAY.

The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick and Prince Edward Island. By H. RIES. Can. Min. Jl. Vol. 31, No. 15, pp. 470–1, and Vol. 31, No. 16, pp. 499–500. (From Summary Report of G. S. C., 1909.)

The important clay-bearing formations are the lower Carboniferous, Millstone Grit, Coal Measures and Pleistocene. Of these the coal measures are the most important in Nova Scotia. Pleistocene clays are classed as (1) glacial-plastic, tough and red burning; (2) marine clays also burning red. In New Brunswick Devonian shales look promising. In Prince Edward Island the only clays are of Pleistocene age. The writer predicts a promising future for these provinces, but development is yet in its infancy. A.

COAL.

The Explosibility of Coal Dust. By G. S. RICE, with chapters by J. C. W. FRAZER, A. LARSEN, F. HAAS, and C. SCHOLZ. U. S. G. S. Bull. 425, 1910, pp. 186 with 14 plates and 28 figures.

Gives historical reviews of coal-dust problem in Europe, and the United States; discusses coal dust and its origin and distribution, experiments with explosive coal dusts, humidity of mine air, remedies for coal dust, tentative conclusions on the dust problem, observations on manifestations of coked coal dust in mine explosions, and special features in dust explosions. Special chapters: laboratory investigations of the ignition of coal dust, coal-dust investigations at European testing stations, exhaust steam as a preventive of dust explosions, and use of steam and water sprays in Oklahoma mines. Selected bibliography. L.

The River Coalfield of Alaska. By L. W. STORM. Eng. & Min. Jl. Vol. 90, No. 6, pp. 272–5.

This field occupies about 75 square miles. The seams are usually large and contain anthracite with 78 to 84 per cent. fixed carbon and 4 to 7 per cent. ash, semi-anthracite, and semi-bituminous coal which corresponds to that of West Virginia. The coal is badly crushed as a result of the folding and contorting of the sediments in late Tertiary times. A.

Coal and Iron Explorations in Oaxaca, Mexico. By J. L. W. BERKINBINE. Eng. & Min. Jl. Vol. 90, No. 14, pp. 668–671.

The coal is of Cretaceous age. The seams vary from a few inches to 6 feet in thickness. The total measured thickness of coal in one field is about 83 feet and that in Tezoathan field is about 64 feet, which

is an anthracite coal. The sediments are cut by Tertiary andesites and basalts which have had no effect on the coal even within 20 feet of the contact. The iron ores are magnetite, hematite and limonite and are found to be of a high grade. The deposits are low in sulphur and phosphorus. A.

Geologic Bearing of the Peat Beds of Anticosti Island. By W. H. TWENHOFEL. Amer. Jour. Sci. Vol. XXX, 1910, pp. 65–71.

Describes an interesting growing peat deposit, and lays emphasis on the fact that a relatively cold climate may support a luxuriant plant growth; also that coal deposits of continental origin may have many of the characters of marine deposits. L.

The Carthage Coal Field, New Mexico. By J. H. GARDNER. U. S. G. S. Bull. 381, 1910, pp. 452–460.

Gives general geology, character of coal, and mine descriptions. The only workable bed is of excellent quality. L.

The Coal Field between San Mateo and Cuba, New Mexico. By J. H. GARDNER. U. S. G. S. Bull. 381, 1910, pp. 461–473.

Gives general geology and describes the coal beds (with sections). The field has not been prospected, and no fresh samples are yet available for analyses. L.

The Trinidad Coal Field, Colorado. By G. B. RICHARDSON. U. S. G. S. Bull. 381, 1910, pp. 379–446.

Gives stratigraphy and structure, describes the several coal districts, the character of the coal, development and statistics of available amount, production and value. Coals include coking and non-coking varieties, and natural coke (metamorphosed by sills of igneous rock). L.

Isolated Coal Fields in Santa Fe and San Miguel Counties, New Mexico. By J. H. GARDNER. U. S. G. S. Bull. 381, pp. 447–451.

Brief account of coals in the Omara field and along the Pecos River. L.

The Colorado Springs Coal Field, Colorado. By M. I. GOLDMAN. U. S. G. S. Bull. 381, 1910, pp. 317–340.

Gives general geology, detailed sections and analyses of the coal, development and markets. L.

The Canon City Coal Field, Colorado. By C. W. WASHBURNE. U. S. G. S. Bull. 381, 1910, pp. 341–378.

Gives geology, stratigraphic position of coal beds, descriptions of mines and prospects, character of the coal (with analyses) and eco-

nomic conditions. The coal is a high grade domestic fuel, non-coking, clean to handle, and of excellent keeping quality. L.

Coal of the Denver Basin, Colorado. By G. C. MARTIN. U. S. G. S. Bull. 381, 1910, pp. 297–306.

Report of a reconnaissance examination, with several analyses. L.

The South Park Coal Field, Colorado. By C. W. WASHBURNE. U. S. G. S. Bull. 381, 1910, pp. 307–316.

Gives stratigraphic position, distribution, and character of the coal—a bituminous coal of good steaming quality. The future of the field depends on the discovery of beds of workable thickness. L.

Weathering of Coal in the Arid Region of the Green River Basin, Sweetwater County, Wyoming. By A. R. SCHULTZ. U. S. G. S. Bull. 381, 1910, pp. 282–296.

Describes the zones of surface weathering, underground weathering, and unaltered coal, and illustrates with analyses of coal from several localities. The belt of weathering is divided into two members: Coal in the upper or surface zone has suffered marked oxidation; in the lower part apparently shows no greater weathering effect than the coal below ground water level. L.

The Southern Part of the Rock Springs Coal Field, Sweetwater County, Wyoming. By A. R. SCHULTZ. U. S. G. S. Bull. 381, 1910, pp. 214–281.

A brief discussion of the economic geology of the district, giving topography, geologic structure, stratigraphy (with several sections), properties of the coal (with several analyses) development in the several mines, mining operations, future development, markets, and available coal. L.

The Coal Field in the Southeastern Part of the Big Horn Basin, Wyoming. By E. G. WOODRUFF. U. S. G. S. Bull. 381, 1910, pp. 170–185.

Preliminary report of geology, and occurrence, development, character, and amount of coal. L.

The Eastern Part of the Little Snake River Coal Field, Wyoming. By M. W. BALL and E. STEBINGER. U. S. G. S. Bull. 381, 1910, pp. 186–213.

Gives general geology, properties of the coal, present and future development. L.

The Powder River Coal Field, Wyoming, adjacent to the Burlington Railroad. By R. W. STONE and C. T. LUPTON. U. S. G. S. Bull. 381, 1910, pp. 115–136.

Preliminary description of topography, geology, the several coal beds, character and utilization of the coal. L.

The Buffalo Coal Field, Wyoming. By H. S. GALE and C. H. WEGEMAN. U. S. G. S. Bull. 381, 1910, pp. 137–169.

Describes topography, physiography, structure, properties, correlation, and distribution of the coal. L.

The Milk River Coal Field, Montana. By L. J. PEPPERBERG. U. S. G. S. Bull. 381, 1910, pp. 82–107.

A preliminary statement of topography, geology, character of coal, conditions of mining and transportation, and future development (for local demands). L.

Notes on the Coals of the Custer National Forest, Montana. By C. H. WEGEMAN. U. S. G. S. Bull. 381, 1910, pp. 108–114.

Gives brief statements of topography, geology and the several occurrences. L.

The Fort Peck Indian Reservation Lignite Field, Montana. By C. D. SMITH. U. S. G. S. Bull. 381, 1910, pp. 40–59.

Describes topography and geology, occurrence, distribution and future development of the lignite, which will probably have only local use. L.

The Central Part of the Bull Mountain Coal Field, Montana. By R. W. RICHARDS. U. S. G. S. Bull. 381, 1910, pp. 60–81.

A preliminary statement giving general geology, detailed descriptions of coal beds, physical and chemical properties and development of the coal. L.

The Washburn Lignite Field, North Dakota. By C. D. SMITH. U. S. G. S. Bull. 381, 1910, pp. 19–29.

Briefly outlines stratigraphy and structure and describes individual lignite beds. L.

The Fort Berthold Indian Reservation Lignite Field, North Dakota. By C. D. SMITH. U. S. G. S. Bull. 381, 1910, pp. 30–39.

Describes topography, geology, and occurrence, distribution, and future development of the lignite, which will probably "have only a local use for many years to come." L.

Stratigraphy and Coal Beds of the Indiana Coal Field. By G. H. ASHLEY. U. S. G. S. Bull. 381, 1910, pp. 9–18.

Describes the general occurrence with typical section, and describes the individual beds. L.

GRAPHITE.

Supposed Deposits of Graphite near Brigham, Utah. By H. S. GALE.

Gives analyses showing that a black member of a schist series, thought to contain graphite, contains only from 3.5 to 5.6 per cent. of coaly substance which can be burned off by an ordinary bunsen flame. The ash is light gray and contains no graphite. The material may prove of value in paint manufacture. L.

MICA.

Mica Deposits of North Carolina. By D. B. STERRETT. U. S. G. S. Bull. 430–J, 1910, pp. 3–48.

Considers the characteristics, distribution and occurrence of mica (in pegmatite), outlines the general geology, and describes the individual mines.

MINERAL PAINTS.

Ocher Deposits of Eastern Pennsylvania. By J. C. STODDARD and A. C. CALLEN. U. S. G. S. Bull. 340–G, 1910, pp. 3–19.

Outlines geography, history, developments, geology, and occurrence of the ocher; explains origin (residual concentration chiefly from Cambro-Ordovician limestone); gives detailed descriptions of mines. L.

Paint-Ore Deposits near Lehigh Gap, Pennsylvania. By F. T. AGTHE and J. L. DYNAN. U. S. G. S. Bull. 340–G, 1910, pp. 20–34.

Gives history, geography, and geology (with several structure sections); describes ore-deposits (a continuous bed between the Marcellus and Oriskany formations of siderite passing up into cement rock, and underlain by shale. The origin is thought due to downward circulating water, reduction by carbonaceous (Marcellus) shale, and replacement of the cement rock. Mining methods and preparation of the paint are described. L.

MONAZITE.

An Occurrence of Monazite in Northern Idaho. By F. C. SCHRADER. U. S. G. S. Bull. 340–D, 1910, pp. 36–43.

Gives location and topography, geology, and describes the deposits (placer sands, concentrates of which yield 31.8–35.36 per cent. mona-

zite). Considers origin (from disintegration of granite) and distribution of monazite in northern Idaho. L.

OIL AND GAS.

Geology and Oil Prospects of the Reno Region, Nevada. By R. ANDERSON. U. S. G. S. Bull. 381, 1910, pp. 475–489.

Describes the several rock formations and the limited economic developments. Gives reasons for conclusion that the one possible oil-bearing formation (the Truckee) does not contain oil in paying quantities. L.

Two Areas of Oil Prospecting in Lyon County, Western Nevada. By R. ANDERSON. U. S. G. S. Bull. 381, 1910, pp. 490–493. Neither the region east of Wabuska nor Smith's Valley is thought to warrant further prospecting. L.

Analyses of Crude Petroleum from Oklahoma and Kansas. By D. T. DAY. U. S. G. S. Bull. 381, 1910, pp. 494–503.

States methods of sampling and analysis, and tabulates 105 analyses of petroleum samples from various places. L.

The Madill Oil Pool, Oklahoma. By J. A. TAFF and W. J. REED. U. S. G. S. Bull. 381, 1910, pp. 504–513.

Gives stratigraphy and structure; physical properties, occurrence, and development of the petroleum. The oil is believed to have worked upward from the Carboniferous rocks into the Trinity (Cretaceous) sand. L.

The Florence Oil Field, Colorado. By C. W. WASHBURNE. U. S. G. S. Bull. 381, 1910, pp. 517–544.

Gives general geology, mode of occurrence of the oil, methods of locating wells, extensions of the field, effects of pressure, relation to gas, physical properties, technology, history of production, drilling success and explanation of map showing wells. L.

Oil and Gas in Louisiana, with a brief Summary of their Occurrence in Adjacent States. By G. D. HARRIS. U. S. G. S. Bull. 429, 1910, pp. 192, with 22 plates and 21 figures.

Distinguishes and describes two modes of occurrence—saline dome oil and gas, and stratum oil and gas—with suggestions for prospecting. Gives details of oil and gas fields and prospects, and notes exploitations in barren territory. L.

Bituminous, or Oil-Shales of New Brunswick and Nova Scotia also on the Oil and Shale Industry of Scotland. By R. W. ELLIS. Dept. of Mines Canada. Nos. 55 and 1107, 136 pages, 15 plates, 6 figs., 1910.

Pt. I., Economics, describes the Scottish oil-shale industry, process of extraction and distillation tests.

Pt. II., Geology, deals with the extent and occurrence and character of the oil shales in eastern Canada. A.

Oil Shale Deposits, Blue Mountains, N. S. W. By H. L. JANE. Eng. & Min. Jl. Vol. 90, No. 9, p. 407.

The oil-shale in Australia belongs to the Permo-Carboniferous measures. This shale has been formed by the accumulation of spores and seeds from the plant life which was abundant in swamps and lagoons during that period. The shale is divided into two classes, (1) Export or gas shale—which contains at least 60 per cent. of volatile hydrocarbons and which is used for the enrichment of ordinary illuminating coal gas; (2) oil or retort mineral which is below 60 per cent. Crude oil is produced from this shale on the ground and is afterwards refined. It has a low specific gravity between 1.08 and 1.5 which indicates a good grade of shale. It is mined without explosives by the "long-wall" system. A.

PHOSPHATES.

Preliminary Report on the Phosphate Deposits in Southeastern Idaho and Adjacent Parts of Wyoming and Utah. By H. S. GALE and R. W. RICHARDS. U. S. G. S. Bull 430–H, 1910, pp. 3–81, with 13 plates and 3 figures.

Describes the nature and origin of the rock phosphate (original oölitic sediments interbedded with phosphatic limestones, shales, and sandstones), the general stratigraphy and structure, and the details of the several districts. L.

Phosphate Deposits east of Ogden, Utah. By E. BLACKWELDER. U. S. G. S. Bull. 340–H, 1910, pp. 82–97, with 4 figures.

Describes geography and general geology; gives distribution, characteristics and relations, and utilization of the deposits (oölitic rock alternating with dark phosphatic limestone and shale); describes deposits by localities. L.

SALINES.

The Salt Resources of the Idaho-Wyoming Border, with Notes on the Geology. By C. L. BREGER. U. S. G. S. Bull. 430–I, 1910, pp. 3–17.

Gives location, mode of occurrence, and chemical composition and quality of the salt, discusses treatment and commercial conditions, and

gives the geology of the district. The salt accumulated in isolated bodies during a long pre-Pleistocene arid period. Its quality is above the average. It could be most cheaply and cleanly prepared by a process of solar evaporation.

BUILDING MATERIALS.

Granites of the Southern Atlantic States. By T. L. WATSON. U. S. G. S. Bull. 426, 1910, pp. 282 with 27 plates and 20 figures.

Chapter I. contains a general discussion of the composition, textures, and structures of granites; the remaining seven chapters deal respectively with the granites of Maryland, Virginia, North Carolina, Tennessee, South Carolina and Alabama. An appendix includes statistics of production and a bibliography. L.

The Economic and Petrographic Geology of the New Red Sandstones of the South and West of Scotland. By R. BOYLE. Trans. Geol. Soc. of Glasgow. Vol. XIII., Part III., 1909.

Summarizes geology of the 8 new red sandstone areas (probably of Permian age); gives general descriptions of the areas; discusses origin of white, decolorized spots and irregular masses in the red rock; discusses chemical composition and petrography of each area giving analyses; discusses the testing of sandstone, giving mathematical demonstration to show that for crushing tests prisms at least one and one-half times as long as square must be used, cubes giving values 8 to 10 per cent. too high; discusses general properties and weathering. L.

WATER-SUPPLY.

Surface Water-Supply of the United States, 1907–8, Part VI. Missouri River Basin. By R. F. FOLLANSBEE and J. E. STEWART. U. S. G. S. Water-Supply Paper 246, 1910, pp. 311, with 13 plates and 2 figures.

Gives measurements on several basins of the Missouri system in Montana, Wyoming, North Dakota, Nebraska, Colorado and Missouri. L.

Surface Water Supply of the United States 1907–8. Lower Mississippi Basin. By W. B. FREEMAN, W. A. LAMB, and R. H. BOLSTER. U. S. G. S. Water Supply Paper 247, 1910, pp.

Gives measurements on streams in the Arkansas River, Red River, and Yazoo River drainage basins. L.

Surface Water Supply of the United States, 1907–8. Part X. The Great Basin. By E. C. LARUE and F. F. HENSAW. U. S. G. S. Water Supply Paper 250, 1910, pp. 151, with 6 plates and 1 figure.

Gives measurements on the several rivers in the Watchung Mt., Humboldt Sink, and Sierra Nevada drainage areas, and of Great Basin drainage in Oregon. L.

ORE DEPOSITS.

The Ultimate Source of Ores. By C. R. KEYES. A. I. M. E. Bull. 43, 1910, pp. 527–550.

Recognizes and discusses four phases of primary ore-genesis: (1) extraction of ore materials from sea-water, (2) metallic content of igneous rocks, (3) magmatic origin of metals, (4) meteoric derivation of the metals. Calls attention to the fact that the majority of the world's productive ore bodies are in the vadose zone, and suggests that fallen meteorites are the main source of ore materials. L.

La Metallogenie de l'Asie Russe. By L. DE LAUNAY. Ann. des Mines, 10 serie, t. XV, p. 220 and p. 303, 1909.

Shows association of the metallogeny with geologic structure and paleography. Illustrates with several maps. L.

Surface Indications of Ore Shoots in Depth. By W. H. STORMS. Min. & Sci. Press. Vol. 101, No. 17, p. 537.

Gives eleven indicators of the occurrence of ore-shoots beneath the surface. (1) A smooth hillside without depressions crossing the strike of lode; (2) gulches or natural depressions across the strike of vein indicate disturbance beneath the surface and hence a discontinued ore shoot; (3) a gorge at the surface; (4) the occurrence of a gorge at the surface does not warrant payable ore shoots below; (5) a seepage of water often found along outcrop of fissure containing ore; (6) in a series of branching or parallel veins pay shoots usually occur *en echelon* and seldom immediately back of each other; (7) distance between pay shoots only determined by development; (8) mineralization along surface; (9) a quartz outcrop is no indication of pay shoots below; (10) development alone determines the value of ore below surface; (11) strike and dip in outcropping veins important. A.

Origin of the Pegmatites of Maine. By E. S. BASTIN. Jour. Geol. Vol. XVIII., No. 4, 1910, pp. 297–320.

Considers geologic relations, mineral composition and texture, and the relative influence of external conditions, major and minor mineral constituents and gaseous constituents in determining pegmatitic texture. That of gaseous constituents are believed most important. Field and laboratory evidence bearing on viscosity and gas content

shows that in most cases the pegmatites are very closely related in behavior and composition (including gaseous content) to normal granite. Study of quartz crystals shows that the finer-grained pegmatites crystallized above, while the coarser, more quartzose and gem-bearing pegmatites crystallized below, 575° C. Chemical and field study shows that the graphic intergrowths are not to be considered eutectics. Broader field relations suggest that the large areas marked by abundant pegmatite intrusions constitute the roof overlying the granite batholith. L.

The Metallogeny of the British Isles. By A. M. FINLAYSON. Quart. Jour. Geol. Soc. (London). Vol. LXVI., No. 262, 1910, pp. 281–298.

Outlines four epochs of sub-crustal and igneous activity, correlates with them the three metallogenic epochs, and classifies the deposits according to epochs and provinces. The epochs are: (1) Pre-Cambrian in Scottish Highlands (magmatic segregations); Post-Silurian (Caledonian) in Scottish Highlands (magmatic segregations, pegmatites, pyritic deposits, fahlbands, gold); (3) Post-Carboniferous (Hercynian) over most of Great Britain and Ireland (veins of copper, gold, silver-lead, zinc, and tin-copper); (4) Post-Cretaceous and early Tertiary (barren). Conclusions are generally similar to those recently reached by Lindgren and by Spurr. L.

REGIONAL REPORTS.

Some Ore Deposits in Maine and The Milan Line, N. H. By W. H. EMMONS. U. S. G. S. Bull. 432, 1910, pp. 62, 3 plates and 23 figures.

Summarizes geology, and gives general description and discussion of ore deposits, which include: (1) Deposits formed before the end of the last period of great regional metamorphism; (2) deposits associated with granite intrusions; and (3) deposits associated with diabase or trap. The first group includes regionally metamorphosed fissure veins and garnetiferous contact deposits. The second includes fissure veins in schist and diorite near intrusive granite; molybdenum sulphide ore associated with pegmatitic phases of the granite, and lead sulphide consolidated with the rock-making minerals of the granite. Most of the deposits are of little or no economic value. Individual mines and properties are described. L.

Geological Survey of New Jersey. Annual Report of the State Geologist for the year 1909. By H. B. KUMMEL. Trenton, N. J., 1910.

Contents: Administrative Report, pp. 1–20; Part I: Report upon the Development of the Passaic Watershed by small Storage Reservoirs, by C. C. VERMEULE, pp. 21–68; Part II., Records of Wells in New

Jersey, 1905–1909, by H. B. KUMMEL and H. M. POLAND, pp. 69-100; Part III., Notes on the Mineral Industry, by H. B. KUMMEL, pp. 101–110. L.

Geology of Haliburton and Bancroft Areas, Ontario, Canada. By F. D. ADAMS and A. E. BARLOW. G. S. C. Memoir 6, No. 1082, 419 pages, 70 plates, 7 figs., 2 maps, 1910.

Contains a detailed study of the nepheline and associated alkali-syenites of Ontario which include most of the economic deposits in the areas. The economic resources are numerous, and are accurately described. These consist of gold, copper, lead, molybdenum, iron, ochre, pyrite, mispickel, mica, talc, graphite, corundum, garnet, apatite, marl, marble and sodalite. A.

The Eastern Canadian Mineral Belt. By S. F. VAN WAGENEN. Min. & Sci. Press. Vol. 101, No. 12, pp. 372–374.

An interesting description of the history and topography of British North America; also an outline of the enormous extent of the mineral belt in which the rocks represent the "original crust of the earth." The greater part of this belt has not been visited by man. The ore deposits found and to be expected are naturally of primary origin with metals of high specific gravity and in the form of sulphides or in native state. The writer anticipates the finding of many radioactive elements in this belt. A.

The Mineral Resources of Newfoundland. By B. SYMONS. Eng. & Min. Jl. Vol. 90, No. 8, pp. 360–363, 1910.

The resources consist chiefly of gold, silver, lead, copper, iron pyrites, hematite, peat, some coal and petroleum. Of these, copper has the widest distribution and greatest importance. The copper usually occurs between serpentine rocks and chloritic schists of dioritic rocks. The ore deposits occur in lower Paleozoic rocks especially.

A description is given of six of the mines in operation. A.

A Geological Journey in Guerrero, Mexico. By J. W. FINCH. Min. & Sci. Press. Vol. 101, No. 16, pp. 496–500.

The country rocks consist of a granodiorite sill injected into shales (probably Comanchean) which have been changed to slates. The ore bodies lie along the lower contact of the granodiorite, replacing the slate. The oxidized zone consists of an iron gossan underlain by quartz sand on the hanging wall and lead carbonate on the footwall. The sulphide zone consists almost entirely of pyrite, with some chalcopyrite, galena and sphalerite filling fissures and replacing the slate. Width of ore body is about 100 ft. A 20-foot band of rich ore containing gold, silver and copper values lies along the foot wall. Miner-

alizing solutions came up later than granodiorite injection. Supposed origin is due to metasomatic replacement from ascending thermal ferruginous solutions, which, towards the last, were richer in copper, lead, gold and silver. A.

Conditions at the Palmilla Mine, Parrol, Mexico. By F. W. SMITH. Eng. & Min. Jl. Vol. 90, No. 6, pp. 259–262.

The ore is of primary origin and occurs in crushed and brecciated zones, almost vertical, in a mass of andesite of post-Cretaceous age. The ore has been brought in during a second period of intrusion, which intruded quartz porphyry, and granite porphyry dikes and crushed the andesite. The ore values are in gold and silver. The ore bodies are of low grade, but with development are enlarging downwards. A.

UNCLASSIFIED.

Mineral Resources of the United States, 1909. U. S. G. S. 1910.

Advanced chapters on: The movement of Lake Superior iron ores in 1909, with map showing distribution of the ores, by J. BIRKINBINE (7 pp.). The production of mineral paints in 1909 (22 pp.) and The cement industry of the United States in 1909 (22 pp.), by E. F. BURCHARD; Coal briquetting in 1909 by E. W. PARKER (17 pp.). The production of monazite and zircon in 1909, by D. B. STERRETT (11 pp.). L.

Geology in Relation to Civil Engineering. By R. BOYLE. Reprinted from "Surveying and the Civil Engineer" (John Smith & Son, Glasgow, Scotland).

A paper written for those unfamiliar with the applications of geology, illustrating the use of geologic and petrologic data, in the field and on maps, in connection with excavation, borings, and constructive work. Illustrations from Great Britain and the United States are given. L.

Annual Report of the Minister of Mines for the year 1909. British Columbia. 298 pages, 39 illustrations, 1 map.

This is an account of the mining industries in the province of British Columbia for 1909. A.

Summary Report of the Geological Survey Branch of the Department of Mines, Canada, 1909. No. 1120, 307 pages.

A report of progress for the year 1909. Contains the Director's report and individual reports from the Staff field work. The number of parties in each province were as follows: Yukon, 1; British Columbia, 11; Alberta, 1; Saskatchewan, 1; Ontario, 1; Quebec, 2; New Brunswick, Nova Scotia and Prince Edward Island, 7. A.

SCIENTIFIC NOTES AND NEWS[1]

A. J. COLLIER, formerly of the U. S. Geological Survey, is head of the Department of Geology, University of Oregon.

WALDEMAR LINDGREN during October and November gave a course of lectures in economic geology at Massachusetts Institute of Technology.

THE LAND CLASSIFICATION BOARD of the U. S. Geological Survey, which was created as a section of the Geologic Branch in December, 1908, and which consists of an advisory committee, and separate classification boards for coal, metalliferous deposits, phosphate, oil and gas, and non-irrigable lands, is being reorganized. This is due to the resignation of Mr. Veatch and other members of the various boards and to the constant growth in the work of the section. By virtue of these reorganizations, which will become effective January 1, 1911, the section will be constituted as follows: W. C. Mendenhall, in charge of the section; W. R. Calvert, chairman of the Coal Board; Max W. Ball, chairman of the Oil, Phosphate, and Metalliferous Deposits Boards; W. B. Heroy, chairman of the irrigation and power boards.

The committees are organized as follows:

Advisory Committee—W. C. Mendenhall, C. W. Hayes, M. O. Leighton, Waldemar Lindgren, M. R. Campbell, A. H. Brooks.

Coal Classification Board.—W. R. Calvert, Max W. Ball, A. L. Beekly, C. T. Lupton.

Oil Classification Board.—Max W. Ball, Robert Anderson, C. H. Wegemann.

Phosphate Classification Board.—Max W. Ball, H. S. Gale, R. W. Richards.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

Metalliferous Deposits Classification Board.—Max W. Ball, H. D. McCaskey, E. S. Bastin.

Irrigation Board.—W. B. Heroy, J. C. Hoyt, O. E. Meinzer.

Power Board.—W. B. Heroy, other members to be named.

THE WEST VIRGINIA MINING ASSOCIATION held a well-attended meeting in Washington, D. C., on December 16.

THE GEOLOGICAL SOCIETY OF AMERICA will hold its annual meeting at Pittsburg, Pa., during holiday week.

THE MINISTER OF PUBLIC WORKS of the Republic of Argentina, Señor Ramos Mexia, has recently adopted a plan for making surveys for the determination of artesian water conditions along the lines of national railways. He contemplates topographical and geological surveys of a character similar to those executed by the U. S. Geological Survey, from which he derived the initial suggestion. He has applied to the U. S. government for the services of a geologist and such assistants as he might need, and our Government has responded cordially to that request. Mr. Bailey Willis has accordingly entered into a contract for the term of two years, to execute topographical and geological surveys for the specific purpose of ascertaining artesian water possibilities in these districts which the minister may designate. With him are associated Mr. Chester W. Washburne, of the U. S. Survey; Mr. J. R. Pemberton, of Stanford University, and Mr. Wellington D. Jones, of Chicago University, as geologists, and Mr. C. L. Nelson and Mr. W. B. Lewis as topographers, and the party sails shortly for Argentina to enter upon the work. While these surveys have a specific purpose, their possibilities of usefulness in developing the natural resources and encouraging settlement in the regions surveyed will not be overlooked, and the work will be founded on those scientific studies, upon which alone practical conclusions can safely rest. Thus it is hoped that a definite contribution to knowledge in geography and geology may be made.

It is desirable to point out that the Argentine government has a geological survey which has been in existence since 1903 in its present organization and which dates back half a century as

a bureau of mines. It is under the direction of Señor E. M. Hermitte, who is assisted by Messrs. Bodenbender, Keidel and Schiller, three German geologists who have done excellent stratigraphic and paleontologic work, particularly in districts of the central Argentine Andes. They have unfortunately not been supplied with maps. The established Bureau of Mines, Geology and Hydrology is under the Minister of Agriculture. The surveys which are about to be made are undertaken by the Minister of Public Works. The two operations are thus officially distinct, but it is hoped and anticipated that they may be mutually helpful.